Management and treatment of health-care waste

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1 Management and treatment of health-care waste

1.1 Definition and Characterisation

1.1.1 Introduction

Waste generated in *health-care facilities* is often associated in the public with high *risk*s of *infection*. As a result for the whole *health-care waste* special treatment methods and waste transport procedures are demanded. A classification of all waste, which is generated in health-care facilities (HCFs), under the title "*infectious*" is not justified and result in cost-pregnant measures without any realisation. The hazard potential of health-care waste must be evaluated according to its type and/or its hygienic-micro-biological contamination, in order to arrive at economically meaningful, ecological, safe and arranged disposal procedures.

This curriculum contains the different categories of the health-care waste (HCW) - also known as hospital, clinical or medical waste -, and the entire problem of the health-care *waste management* (HCWM). The specific requirements to the management in developing countries are considered. It is based mainly on the classification by the World Health Organisation (WHO), because it is an often used basis for classification of HCW – particularly in development co-operation.

Health risks that result from inadequate management of health-care waste inside and outside of a medical facility are also described. In this connection inform the curriculum about international, national and regional regulations and legislative aspects.

Minimal health-care waste management programmes for minor health-care facilities in remote locations and with very limited resources are likewise described as well as management programmes for university hospitals.

This curriculum document does not contain the management of waste from animal health-care/veterinary facilities and the specifically collection, treatment and disposal of wastewater from health-care facilities.

1.1.2 Definition

Health-care waste is generated by hospitals, clinics, general practitioners' surgeries, nursing homes, dentists' practices, veterinary practices, laboratories and research establishments and as a result of midwifery and medical care at home.

The largest percentage (between 75% and 90% by weight [1]) of all waste produced in a health-care facility comes from the administrative and housekeeping functions as well as similar waste from wards with patients and may also include waste generated during maintenance of health-care premises is non-risk or “general” health-care waste (HCGW). This waste is comparable to domestic waste.

Only the remainder (between 25% and 10%) is contaminated with chemicals, body fluids or other potential *hazardous* components. This category is a possible source of *injury*, infection or other health or environmental impact. It is known as hazardous or special health-care waste or health-care risk waste (HCRW). Most of HCRW poses an infection risk. A small fraction (generally less than 1%) may pose a physical, radiological or chemical hazard [2]. The disposal of body- and organ parts, e.g. from pathology and operational sectors, must be accomplished under ethical and aesthetic criteria.

1.1.3 Classification by WHO

Several classification systems are used for the characterisation of the different categories of health-care wastes. The WHO suggested the classification of HCW, which is described in following sections (2.1.3.1 to 2.1.3.2). A summarise is given in Tab 5.

Other classification systems by different organisations or countries are described in section 1.1.4.

1.1.3.1 General health-care waste

General health-care waste consists essentially of packing materials such as cardboard boxes, plastic packing and glass, of office materials such as waste paper and consumer goods as empties colour-cartouches of printers and copiers. In workshops additionally metal and plastic scrap irons result, as well as retired devices and inventory. In kitchens the waste consists additionally of remainders of the meal preparation and expenditure for meal. [3]

In areas of patient treatment general waste is generated too, e.g. gift packing, magazines and flower decoration, which is bring along by guests of the patients.

This curriculum document is concerned primarily with health-care risk waste; general wastes can be managed by the municipal waste services dealt with by the domestic waste disposal mechanisms. Such waste can disposed of in a municipal landfill, after removal of material for reuse or recycle took place.

1.1.3.2 Hazardous waste

Infectious waste

This category is suspected to contain *obligate pathogenic* agents or *facultative* pathogenic agents in sufficient concentration or quantity so that they pose a serious threat and requires within and outside the health-care facilities special attention.

Waste items contaminated with body fluids and tissues harbour human pathogens are the major component of this category. Table 1 count up the substantial diseases, which may be communicated by infectious wastes particularly in developing countries.

Tab 1 Diseases, which are communicable by injuries in association with infectious waste

Infectious disease	
AIDS	Mycoplasmosis
Blastomycosis	Scrub Typhus
Brucellosis	Sporotrichosis
Diphteria	Syphilis
Ebola Fever	Toxoplasmosis
Hepatitis B	Tuberculosis
Herpes	Malignancy
Source: [3]	

This category includes:

- wastes from infected patients in infection and isolation wards (e.g. dressings, excreta, clothes heavily soiled with human blood or other body fluids);
- wastes from autopsies and surgery on patients with infectious diseases (e.g. tissues, materials that have been in contact with blood or other body fluids);
- cultures and stocks of infectious agents from laboratories;
- waste that has been in contact with infected patients undergoing haemodialysis (e.g. dialysis equipment such as tubing and filters, disposable towels, gowns, gloves and aprons);
- infected animals from laboratories;
- other materials having been in contact with infected persons and animals. [1]

Pathological waste

Body parts, tissues, organs, human foetuses, blood and body fluids are pathological waste. Additionally rank among animal carcasses. Recognisable human or animal body parts are also called anatomical waste. The WHO pretends that this sub-category should be considered as potential infectious waste, even though it may also include healthy body parts [1].

Note: The disposal identifiable human remains of has to cope with cultural and religious customs. Identifiable human remains should not enter the waste stream in various countries. Especially in Asia religious beliefs require that human body parts be returned to a patient's family, in tiny "coffins", to be buried in cemeteries. The Muslim culture generally requires that body parts are buried. Anatomical waste should in no circumstances dispose of inappropriately, such as on a landfill. [1], [2]

Chemical waste

The discarded chemicals are present gaseous, liquid and/or solid and are possibly injurious to health. If it has one of the following properties at least:

- flammable;
- toxic;
- corrosive (e.g. acids of pH < 2 and bases of pH > 12);
- reactive (explosive, water-reactive, shock-sensitive);
- *genotoxic* (e.g. *cytostatic* drugs)

chemical waste is considered to be hazardous. [1]

Types of hazardous chemicals used most commonly in maintenance of health-care facilities are formaldehyde and solvents. Chemicals as amino acids and inorganic salts are normally non-hazardous.

Waste with high content of heavy metals

Waste with high heavy-metal content is potentially highly toxic and represent a subcategory of hazardous chemical waste. In addition counts above all cadmium from discarded batteries and mercury from spilled or discarded thermometers or manometers. Mercury is present also in small quantities in mercury vapour lamps. Lead is still used radiation proofing of X-ray and diagnostic departments. It is considered as a sub-category of chemical waste but should be treated specifically.

Hazardous pharmaceutical waste

This category includes expired, no longer needed pharmaceuticals; containers and/or packaging, items contaminated by or containing pharmaceuticals, such as bottles or boxes with residues, gloves, masks, connecting tubing, and drug vials.

Hazardous pharmaceutical waste also includes all the drugs and equipment used for the administration (mainly remains by abort of application) and mixing of *cytotoxic* drugs. Cytotoxic waste is dealt with in separate section, since it is a split highly hazardous category.

Pressurised containers

Gases like compressed air and anaesthetic gases are often stored in pressurised cylinders, cartridges, and aerosol cans. Most of pressurised containers are reusable and go back to deliver. Whether containing inert or potential harmful gas and aerosol, containers may explode if incinerated or accidentally punctured and should be collected separate and handled with care.

1.1.3.3 Highly hazardous waste

Radioactive waste

The category of *radioactive* waste includes solids, liquids and gas contaminated with radionuclides whose ionising radiation's have genotoxic effects. It generate from in vitro analysis of body tissues and fluid, in vivo body organ imaging, tumour localisation and therapeutic procedures [4]. Radioactive waste is only produced by nuclear medicine departments at major hospitals or research facilities.

Ionising radiation's usually cause no immediate effects unless an individual receives a very high dose. The specific process of continuously spontaneous decay (admits as "radioactive decay") is accompanied by the emission of one or more types of radiation. Radioactive substances are genotoxic, since these emissions causes the ionisation of *intercellular* material. In medicine mainly ionising radiation's occur in form of X-rays, α- and β-particles, and γ-rays emitted by radioactive substances.

X-rays from X-ray tubes are emitted only when generating equipment is switched on whereas α- and β-particles and γ-rays emit radiation's continuously.

The penetration power of γ-rays is high and shielding (by lead or thick concrete) is required to reduce their intensity. On the other hand *α-particles* have a low penetration power. They are hazardous mostly when inhaled or ingested. *β-Particles* have a significant ability to penetrate human skin. Health impacts caused through ionisation of intracellular proteins and *proteinaceous* components.

Radionuclides have a characteristic half-life, which is constant and by which it may be identified. With the noticeable exception of Cobalt ^{60}Co, the half-life of the most common radionuclides used in nuclear medicine is reasonably short. This type of radioactive material is normally left to decay naturally before leaving the medical treatment area. Radionuclides from therapeutic procedures with longer half-lives are usually in the form of pins, needles, or "seeds". Needles and seeds can be sterilised and reused on other patients. Pins are mostly single-use-articles. The largest amount of radioactive health-care waste is generated by the use of long-life material (particular ^{3}H and ^{14}C) for research purposes [1].

The activity is measured in becquerels (Bq = 1 disintegration per second) or in curie (1Ci = $3{,}7 \times 10^{10}$ Bq). Radioactive material used in health-care facilities usually results in low-level radioactive waste (<1MBq). [1]

Liquids that are applied directly and not encapsulated during use are usually "unsealed" sources. Substances contained in parts of equipment or apparatus or encapsulated in unbreakable or impervious objects are designated as “sealed” sources and may be of fairly high activity. This format is only generated in low volumes from larger medical and research laboratories. [1]

Table 2 shows examples of radionuclides used in HCFs, including information about emission, format, half-life and specific application.

Tab 2 Radionuclides used in health-care facilities

Radionuclide	Emission	Format	Half-life	Application
^{3}H	Β	Unsealed	12,3 years	Research
^{14}C	Β	Unsealed	5730 years	Research
^{51}Cr	Γ	Unsealed	27,8 days	In-vitro diagnosis
^{60}Co	Β	Sealed	5,3 years	Diagnosis, therapy, research
^{99m}Tc	Γ	Unsealed	6 hours	Diagnostic imaging
^{131}I	Β	Unsealed	8 days	Therapy
^{192}Ir	Β	Sealed	74 days	Therapy
^{222}Rd	Α	Sealed	3,8 days	Therapy
Source: [1]				

In accordance with national legislation and according to the activity levels and half-lives of the radionuclides table 3 gives examples of waste classification and clearance levels.

Tab 3 Radioactive waste classification

Class	Description
Cleared material/waste	Materials containing levels of radionuclides at concentrations described by the International Atomic Energy Agency*
Low-level (short-lived)/ decay waste	Low-level radioactive waste containing short-lived radionuclides only (e.g. with half-lives less than 100 days), that will decay to clearance levels within 3 years of being produced
Low- and intermediate-level short-lived waste (LILW-SL)	Waste that will not decay to clearance levels within 3 years, containing b- and g-emitting radionuclides with half-lives less than 30 years and/or a-emitting radionuclides with an activity less than 400 Bq/g and a total activity of less than 4000 Bq in each waste package
Low- and intermediate-level long-lived waste (LILW-LL)	Radioactive waste that contains radionuclides at concentrations above those for LILW-SL but with heat-generating capacity not exceeding 2kW/m3 of waste
High-level waste (HLW)	Radioactive waste that contains radionuclides at concentrations above those for LILW-SL and with heat-generating capacity above 2kW/m3 of waste

* IAEA (1996). Clearance levels for radionuclides in solid materials. Vienna, International Atomic Energy Agency (TECDOC 855). * IAEA (1996). International basic safety standards for protection against ionizing radiation and for the safety of radiation sources. Vienna, International Atomic Energy Agency (Safety Series, No. 115).
Source: [1]

Genotoxic/cytotoxic waste

Spilled or discarded substances which may have *mutagenic*, *teratogenic* or *cancerogenic* properties are summarised by term: genotoxic or cytotoxic waste. Thus it need within and outside the health-care facilities special attention.

The principal substances are cytostatic drugs used to block the growth of cancer cells (chemotherapy). They achieve this by influencing cell metabolism during the cell cycle. Faeces, urine, or *vomit* from patients treated with cytostatic drugs, chemicals, and radioactive material should be also separate.

Beside the cancer therapy this type of highly hazardous substances are also find in further application as immunosuppressive agents in organ transplantation and in treating various diseases with an immunological basis. [1]

Cytotoxic wastes can include:

- contaminated materials from drug preparation and administration, such as syringes, needles, gauges, vials, packaging;
- outdated drugs, excess (leftover) solutions, drugs returned from the wards (to the in-plant pharmacy);
- urine, faeces, and vomit from patients, which may contain potentially hazardous amounts of the administered cytostatic drugs or of their metabolites and which should be considered genotoxic for at least 48 hours and sometimes up to 1 week after drug administration.

Selected cytostatic substances used in health care are listed and differentiated after mutagenicity and cancerogenicity (in vitro) in following table.

Tab 4 Cytostatic substances differentiated after mutagenicity and cancerogenicity

Cytostatic substances	Mutagenicity in vitro	Cancerogenicity in vitro
Adraimycin	+	+
Daunomycin	+	+
Cyclophosphamide	+	+
Isophosphamid	+	+
Cisplatin	+	?
Nitrogen mustard	+	+
Melphalan	+	+
Actinomycin D	-	+

Belomycin	-	+
Source: [5]		

Normally in health-care facilities genotoxic waste occurred in small quantities. However in specialised oncological facilities, genotoxic waste may constitute as much as 1% of the total health-care wastes and their proper treatment or disposal raises serious safety problems. [1]

Sharps

Items which can cause cut- and puncture injuries if improper used and which are contaminated certainly with blood and/or its components after use, such as scalpels and cannulas, can transmit infectious diseases even if the pathogen-contamination-level is low. For these reasons, waste according to these properties is embraced by the category “sharps” and is usually considered as potential infectious and highly hazardous health-care waste, whether contaminated with infectious material or not.

Following items are among consequently:

- needles and *hypodermic needles*,
- scalpel and other blades,
- knives and saws,
- infusion sets,
- broken glass, and nails. [1]

Highly infectious waste

Microbial cultures and stocks of highly infectious agents, such as cholera, typhoid fever and SARS, are highly hazardous. Waste from autopsies, animal bodies, and other waste items that have been inoculated, infected, or in contact with such agents is called highly infectious waste too. This category generates mainly in medical analysis laboratories and involves particularly high attention at collection, transport, treatment and disposal. Body fluids of patients with highly infectious diseases are also included. As a precaution the completely waste by these patients should be treated as hazardous, also actually general waste.

1.1.3.4 Tabulating

Tab 5 Categories of health-care waste by WHO

Waste category	Description	Examples
General	Waste not contaminated with pathogens or chemicals	Office materials, packaging materials
Hazardous waste		

Infectious waste	Waste suspected to contain pathogens	Laboratory cultures; waste from isolation wards; tissues (swabs), materials, or equipment that have been in contact with infected patients; excreta
Pathological waste	Human tissues or fluids	Body parts; blood and other body fluids; foetuses
Pharmaceutical waste	Waste containing pharmaceuticals	Pharmaceuticals that are expired or no longer needed; items contaminated by or containing pharmaceuticals (bottles, boxes)
Chemical waste	Waste containing chemical substances	Laboratory reagents; film developer; disinfectants that are expired or no longer needed; solvents
Wastes with high content of heavy metals		Batteries; broken thermometers; blood-pressure gauges
Pressurised containers		Gas cylinders; gas cartridges; aerosol cans
Highly hazardous waste		
Highly infectious waste	Waste contaminated with highly infectious agents	Laboratory cultures and stocks of highly infectious agents, body fluids of patients with highly infectious diseases
Sharps	Sharp waste	Needles; infusion sets; scalpels; knives; blades; broken glass
Genotoxic/cytotoxic waste	Waste containing substances with genotoxic properties	Waste containing cytostatic drugs (often used in cancer therapy); genotoxic chemicals
Radioactive waste	Waste containing radioactive substances	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
Sources: [1] , [6]		

1.1.4 Classification by other organisations and/or countries

Unfortunately world-wide no uniform categorisation of health-care waste takes place. By the work within the ranges of the health service and the waste disposal it is helpfully to know the classification of some other organisations. Some terms are in different organisations differently or insufficiently defined. Selected classification-systems are given in following sections and tables.

1.1.4.1 Classification in the USA

In the USA health-care waste is generally defined under federal or state regulation. In principle three types of hazardous waste arising in HCFs are differentiated:

- radioactive waste,
- chemical waste and
- potential infectious waste.

Relating to the definition of infectious waste most HCFs adhere to the recommendation of the Centres for Disease Control (CDC) [7]. That agency has assessed which waste items have a reasonable potential to transmit disease. In the recommendation the following items are specified, which are to be considered as potential infectious:

- contaminated sharps (needles, scalpels, pipettes, glass slides),
- microbiology laboratory waste,
- bulk blood and blood products,
- pathology waste and waste and
- waste from what is called class 4 communicable disease isolation patients [7].

1.1.4.2 Classification in the European Union

In the European Union waste categories are specified in form of numeric codes in the European Waste Catalogue (EWC), which is divided into 20 chapters. Chapter 18 has the heading “Wastes from human or animal health care and/or related research (excluding kitchen and restaurant wastes, which do not arise from immediate health care)”. A comparison of HCW categories according to EU Waste Catalogue and WHO is given in following table.

Tab 6 Comparison of HCW categories according to EWC and WHO

EWC		**Categories of health-care waste (WHO)**
code	**Designation**	
180101	Sharps (except 18 01 03)	Sharps
180102	Body parts, and organs including blood bags and preserves (except 18 0103)	Pathological waste
180103*	Wastes whose collection and disposal is subject to special requirements in order to prevent infection	Infectious waste

180104	Wastes whose collection and disposal is not subject to special requirements in order to prevent infection (for example dressings, plaster casts, linen, disposable clothing, diapers)	General waste
180106*	Chemicals which consist or contained of dangerous substances	Chemical waste Waste with high content of heavy metals
180107	Chemicals other than those mentioned in 18 01 06	Chemical waste
180108*	Cytotoxic and cytostatic medicines	Genotoxic waste
180109	Medicines other than those mentioned in 18 01 08	Pharmaceutical waste
180110	Amalgam waste from dental care	Waste with high content of heavy metals
180202*	Wastes whose collection and disposal is subject to special requirements in order to prevent infection	Infectious waste
150111*	metallic packaging containing a dangerous solid porous matrix (for example asbestos), including empty pressure containers	Pressurised containers
National regulation [EU proposal: COM(2003) 32 final]		Radioactive waste
(*) Indicates waste classified as hazardous		
Sources: [8], [9]		

HCW contaminated with facultative pathogenic organisms, e. g. incontinence material, is waste of the EWC-code 180104. This category can cause *nosocomial* infections and involve (only) within the health-care facilities special attention relative the waste management. Waste from patient treatment which is contaminated with obligate pathogenic organisms is at all events infectious (EWC-code 180103). Examples for facultative and obligate pathogenic pathogens are given in Tab 7.

Tab 7 Examples of the allocation of infection exciters to obligate respectively facultative pathogenic

Infection exciters	**Facultative pathogenic**	**obligate pathogenic**
Staphylococcus aureus	x	
Escherichia coli	x	
Candida albicans	x	
Serratia marcescens	x	
Bacillus anthracis		x

Mycobacterium tuberculosis		x
Salmonella typhimurium		x
Human immunodeficiency virus		x

Note: This distinction after obligate and/or facultative pathogenic *germ*s is missing in most of the WHO publications and can lead to increased quantities of infectious wastes. However, in areas with increased infection rates the proceeding of the WHO is justified.

1.1.4.3 Classification for Developing Countries

Developing countries may wish to use a simplified classification for practical purposes. The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) uses and recommends the classification given in following table. This classification system, having four categories instead of eleven, is recommended to limit the number of separate waste collection and storage channels that must be set up within a HCF.

Tab 8 Classification by GTZ

Waste category	**Description**
Type A	Non-infectious waste similarly the general domestic waste
Type B	Infectious waste inclusive of sharp edged components such as syringes, cannulas, glass ampoules
Type C	Pathological waste e.g. organ parts, fabrics, placentas and bacteriological cultures
Type D	Hazardous waste e.g. chemicals, solvent, medicines run off, cytostatic and radioactive substances
Source: [3]	

1.1.5 Sources

The primary sources of HCW are hospitals and clinics with laboratories. While scattered general practitioners, dentists etc. are minor sources. There are considerable characteristic and qualitative differences between HCW being generated by the different health care facilities. While minor health-care facilities only generate some of the above-mentioned categories of HCRW, larger hospitals usually generates all categories of HCRW. For this reason a classification of the facilities after that supplying level is necessary. On the other hand this classification makes a certain statement possible about the level and the basic conditions of the waste management in these facilities.

Major sources with the respective performance specifications are listed in Tab 9.

1.1.5.1 Major Sources

The composition of HCW differs also within large facilities. Different units or wards would generate waste with different characteristics:

- Medical wards in general, district and university hospitals generate mainly infectious waste such as bandages, sticking plaster, gloves, disposable medical items, used hypodermic needles and intravenous sets, body fluids and excreta, contaminated packaging, and meal scraps. [1]
- Ranges of transfusions generate mainly blood and blood products, particularly as blood bags and preserves.
- Highly infectious waste is particularly generating by laboratories in the form of small pieces of tissue, microbiological cultures, and stocks of infectious agents or infected animal carcasses.
- In-plant pharmacies generate small quantities of pharmaceutical, chemical and cytotoxic wastes.

The categories of HCW produced by various types of units or wards are indicated in Tab 10.

Tab 9 Major sources of health-care waste

Facility	Respective performance specifications
University- , General-, National referral Hospital	• Special service for complicated health problems • Teaching, research and development • Outpatient clinic enterprise • Operational supply of emergencies and other interferences (Birth assistance, surgery including traumatology, urology) • Conservative treatment of severely ill people • Technically complex diagnostics (X-ray, ultrasound, lab) • Advanced training (also the personnel of the minor health centers) • Studies and operational research • Participation in the supervision of the health centers • Maintenance system
District Hospital	Like University Hospital but without: • Special service for complicated health problems • Teaching, research and development

Rural-, Primary Hospital (mainly in villages and remote areas)	Curative supply acutely and chronically patients, as far as no medical authority is necessary (generally about 80 % all illness - and welfare cases) • Pregnant woman precaution • Birth support and family planning • Infant welfare service (inclusively inoculating and growth control) • Municipality promotion (primary prevention, technical support of traditional midwives etc.) • Supervision of minor health posts and centers, • Stationary treatment, laboratory test, X-ray and simple operations
Health-care centres, clinics and dispensaries	Like Rural Hospital but without: • Supervision of minor health posts and centers, • Stationary treatment, laboratory test, X-ray and simple operations
Other special health-care facilities: • Emergency medical care services, obstetric and maternity clinics, outpatient clinics, dialysis centre, first-aid posts and sick bays, transfusion centres, military medical services • Related laboratories and research centres, mortuary and autopsy centres, animal research and testing, Blood banks and blood collection services, nursing homes for the elderly	
Sources:[1], [3]	

Tab 10 Categories of HCW produced by various types of units or wards

Source	Waste Category							
	Legend: 1: General, 2: Pathological, 3: Radioactive, 4: Chemical, 5: Infectious, 6: Sharps, 7: Pharmaceutical, 8: Pressurised Containers							
	1	2	3	4	5	6	7	8
PATIENT SERVICES								
Medical	X	X[a]		X	X	X	X	X
Surgical	X	X		X	X	X	X	X
Operating Theatre	X	X		X	X	X	X	X
Recover & Intensive Care	X	X[a]		X	X	X	X	X
Isolation Ward	X	X[a]		X	X	X	X	X
Dialysis Unit	X	X[a]		X	X	X	X	
Oncology Unit	X	X[a]		X	X	X	X	X
Emergency	X	X		X	X	X	X	
Out Patient Clinic	X	X[a]		X	X	X	X	
Autopsy Room	X	X		X	X	X		
Radiology	X	X[a]		X	X	X		

LABORATORIES								
Biochemistry	X	X[a]	X	X	X	X		
Microbiology	X	X[a]	X	X	X	X	X	
Haematology	X	X[a]	X	X	X	X		
Research	X	X	X	X	X	X		
Pathology	X	X	X	X	X	X		
Nuclear Medicine	X	X[a]	X	X	X	X		
SUPPORT SERVICES								
Blood Bank	X	X[a]	X	X	X			
Pharmacy	X		X					
Central Sterile Supply	X		X					
Laundry	X		X		X			
Kitchen	X							
Engineering	X		X		X			
Administration	X							
Public Areas	X							
LONG TERM HEALTH-CARE FACILTIES	X			X	X	X	X	
X[a]: Blood and body fluids, Source: [4]								

1.1.5.2 Minor Sources

Scattered sources, such as home health-care, generally generate mainly infectious waste and some to many sharps. Other hazardous health-care waste categories do not develop and/or in very small quantities. Specialised health-care facilities generate different waste categories in dependence of the respective adjustment. Small quantities of health-care waste is generating by non-health activities to, such as cosmetic (ear-) piercing and funeral services. Following table shows some examples of minor (and scattered) sources of HCW.

Tab 11 Minor sources of health-care waste

Small health-care facilities • Dental clinics • Physicians' offices • Acupuncturists • Chiropractors
Specialised health-care facilities and institutions with low waste generation • Psychiatric hospitals • Convalescent nursing homes • Institutions for disabled persons
Non-health activities involving intravenous or subcutaneous interventions • Cosmetic ear-piercing and tattoo parlours • Illicit drug users

Funeral services
Ambulance services
Home treatment
Source:[1]

1.1.6 Health-care waste generation

The generation-rate and composition (see about section 1.1.7) of health-care wastes depend on numerous factors, like generally also. It differs not only from country to country but also within a country and even within a facility. The main influence quantities are:

- the type of health-care facility,
- the hospital specialisation,
- the number of beds (stationary treated patients),
- the number of ambulatory treated patients,
- the alignment in research and teachings.

Apart from these static factors existing dynamic factors, which can be affected positive by an optimised waste management. These are mainly:

- the established waste management methods,
- the proportion of reusable items employed in health-care (co-operation of the purchase department),
- the information and the motivation of staff.

Being present different classifications of the categories of health-care waste (see section 1.1.3 and 1.1.4) and the fact that the determination of the quantities of waste is accomplished in different procedures makes it very problematic to compare the resulting quantities of waste with. It is therefore suggested to know the respective foundation of classification.

Note: In developing countries the portion of ambulatory patients of a hospital is importantly higher compared with the stationary treated persons, than in the industrialised countries. A statement concerning the waste generation related to the number of beds and therefore days of the stationary treatment (kg/bed/day) is little meaningful. So a study from Guatemala proves that the treatment of ambulatory patients per patient produces for instance three times as much waste, like those of the stationary patients. [3]

Therefore the following data are viewed only as examples. Conclusions on generating in other countries and/or facilities are only conditionally possible.

1.1.6.1 Generation rates according to national income level

In low- and middle-income countries, waste generation is usually lower than in high-income countries. The same applies also to health-care waste. Tab 12 shows annual waste generation rates according to national income level and per head of population.

Tab 12 Annual generation rates according to national income level

National income level	waste generation (kg/head of population)
High-income countries:	
• all health-care waste	1.1–12.0
• hazardous health-care waste	0,4-5,5
Middle-income countries:	
• all health-care waste	0.8–6.0
• hazardous health-care waste	0.3–0.4
Low-income countries:	
• all health-care waste	0.5–3.0
Source:[1]	

1.1.6.2 Generation rates by country and region

Data from various surveys in different countries and/or regions are summarised in Tab 13 and Tab 14. Differences of amounts between the countries with the same income-level are to be due partially on different definitions (based to different legislation). All indicated values represent the complete waste arising (general and hazardous).

Empirical values from different development-assistance-projects of the GTZ supplemented by other empirical values are indicated in following table. It clarifies the broad span of the available data in industrialised and developing countries.

Tab 13 HCW quantities produced in health-care facilities in different countries and regions

Country or region	Generation (kg/bed, day)
Western Europe*	3-6
Eastern Europe*	1,4-2
Eastern Mediterranean	1,3-3
USA	6,6
Latin America	1-4,5
Brazil	1-7
Botswana	1,7

Eastern Asia -middle income countries*	1,8-2,2
Eastern Asia -high income countries*	2,5-4
Nepal	1,27
India	0,3-2
Guatemala	0,3-7,3
Sources:[3], *:[1]	

Tab 14 below provides data of an investigation in different cities of Pakistan. It becomes apparent how much health-care waste a mega city per day produces. So Karachi as a city with over ten million people alone generates over 100 tons of HCW/day (based on the average generation rate of 0.01/kg/cap./day).

Tab 14 HCW generation in different cities of Pakistan

City	No. of hospitals surveyed	Total No. of beds	Generation Rate (kg/bed/day)
Karachi	5	3.500	1,20
Lahore	6	4.188	1,05
Rawalpindi	9	1.552	0,99
Multan	4	1.235	1,46
Faisalabad	9	1.546	1,00
Gujranwala	9	1.037	0,98
Sargoda	6	435	0,71
	48		1.06 (mean value)
Source:[4]			

1.1.6.3 Generation rates according to type of source

Generation of health-care waste is according to type of the respective facility. Some selected empirical values from different countries are indicated in following tables.

The following figures show total amounts of health-care waste (including non-hazardous waste) generated in some industrialised countries.

Tab 15 Generation (kg/bed/day) according to type of facilities in some industrialised countries

Type of HCF	Norway	Spain	UK	France	USA	NL
University hospital	3.9	4.4	3.3	3.35	5.24	4,2 - 6.5
General hospital				2.5	4.5	2.7
Maternity		3.4	3.0			
Mental hospital		1.6	0.5			1.3

Geriatric care		1.2	9.25			1.7
Source:[10]						

Tab 16 Generation rates according to the bed-size

Bed-size	Total waste generation rates			
	(kg/bed/day)	(lbs/bed/day)	(kg/patient/day)	(lbs/patient/day)
< 100	2,59	5,71	5,13	11,3
100 - 299	4,70	10,4	7,16	15,8
300 - 499	5,67	12,5	8,63	19,0
> 500	5,83	12,8	7,69	16,9
Total Av.	4,18	9,21	6,93	15,3
Source:[8]				

Tab 16 shows the dependence on number of beds and/or of patients and generation-rate. From the numerical values the tendentious statement can be derived that with more rising bed-size the average total quantity of waste per patient and/or bed and day increases. This is to lead back predominantly on the more extensive offer at medical services of a hospital of the maximum supply opposite a hospital of the rule supply. Furthermore, not neglecting reason for the rising quantity of waste per bed with rising bed number of a medical facility is, that HCFs of the maximum supply have a higher number at intensive beds than smaller mechanisms, and the waste quantity, which develop at intensive beds, is very much higher than at beds for normal nursing care.

In HCFs with a bed-size between 300 and 500 a deviation from the patient-referred trend can be determined. A reason for the fact could be the smaller number at out-patients, in comparison with larger facilities.

An investigation in separated facilities of different size in Botswana (sponsored by the GTZ) furnished the results represented in Tab 17. A distinction of sharps, medical and general waste took place. The values are indicated only partially in kg/bed/day.

Tab 17 Generation according to type of facilities in Botswana

Facility	Medical (kg/day)	Sharps (Container)*	Household (kg/day)
Reference and district hospitals	0.75 (per bed)	1.5/100 beds	3/bed
Private hospitals	1.0 (per bed)	2/100 beds	4/bed
Primary hospitals	0.5 (per bed)	1/100 beds	2/bed
Clinics with beds	20.0	2/month	40
Clinics	15.0	2/month	30
Health posts	5.0	1/month	10
Medical and vet practices	2.5	1/month	5
Source:[11], based on classification by the GTZ, *: size: 4 liters			

An optimal HCWM within facilities require the knowledge not only of the total arising but also of the arising in individual wards or units. The knowledge of facility-internal waste streams is an important component of the HCWM and represents the basis for the conversion of requirements at collection, transport, storage and treatment of the resulting waste. The daily resulting generation-rates of waste can strongly vary and should be intended separately for each (major) facility. An extensive investigation of generation-rates of HCW at different hospitals in Karachi (Pakistan) is to find in [4].

1.1.6.4 Generation rates according to type of waste

The basic engineering of disposal-logistic instruments, such as waste treatment units, requires the knowledge from daily resulting quantities of waste partitioned after the waste categories and sources, particularly for hazardous health-care wastes.

Tab 18 contains selected empirical values of an investigation in a German university hospital of the maximum supply (bed-size > 500). These values of the daily accumulated waste generation-rate are only orders of magnitude to show. The rate depends strongly on the factors specified above.

Tab 18 Generation-rates according to the type of waste (German university hospital)

Source type	**Daily waste generation (kg/day)**		
	Infectious (human care)	Pathological	Genotoxic
Central laboratory (clinical chemistry)	43,5	0,5	-
Pharmacy (in-plant)	-	-	0,1
Daily hospital - Neurology	0,1	-	-
Operating theatre	2,6	1,2	0,1
Blood transfusion	-	17,3[a]	-
Dermatology	3,9	1,0	-
Neurology	1,6	0,2	

[a]: mainly blood and body fluids, Source: [12]

The WHO indicates for developing countries that have not performed their own surveys of health-care waste following approximate values:

- general health-care waste: 80%;
- pathological and infectious waste: 15%;
- sharps waste: 1%;
- chemical or pharmaceutical waste: 3%;
- special hazardous waste, such as radioactive or cytostatic waste, pressurised containers, or broken thermometers and used batteries: less than 1%. [1]

1.1.7 Characterisation and composition

The knowledge of composition and some physicochemical parameters is important for a number of applications in waste management, i.e.:

- selection and dimensioning of treatment plants,
- determination of storage space,
- dimensioning of the collection vehicle size,
- location and dimensioning of recyclable waste containers .

A closer investigation of the HCW-streams reveals that many items are recyclable materials amenable to waste *minimisation*. The composition of the waste depends thereby on the factors (already mentioned) and varies within the countries and within the facilities. Following table contains results of an analysis of HCW in Peru.

Tab 19 Composition of Hospital Wastes in Peru (% by weight)

Material	Range of amount
Paper	15,6 – 37,0
Cardboard	0,0 – 9,8
Plastic	9,1 – 15,8
Plaster	0,0 – 3,7
Placenta, others	0,0 – 21,7
Glass	4,0 – 14,4
Cotton, gauze	12,3 – 26,5
Others	21,5 – 33,5
Source: [14] quoted in [13]	

A particularly important parameter to develop an efficient HCWM system is the bulk density of waste or components of the waste. Tab 20 exemplifies results of analysis conducted in North America. It becomes apparent that the values are heavily varying.

Tab 20 Bulk density of HCW in North America

Component	Bulk density [kg/m³]
Human anatomical	82 to 1202
Plastics	80 to 2308
Swabs, absorbents	80 to 994
Alcohol, disinfectants	769 to 994
Infected animals	482 to 1282
Glass	2805 to 3607
Bedding, shaving, paper, fecal matter	321 to 737
Gauze, pads, swabs, garments, paper, cellulose	80 to 994
Sharps, needles	7214 to 8015
Fluids, residuals	994 to 1010
Source: [15] quoted in [13]	

Further characteristic parameters, such as the heating value of infectious waste, are important, especially if a treatment plant is planed. An assortment of typical parameters of infectious waste shows the following table.

Tab 21 Typical characteristics of infectious waste

Typical Characteristics	
Moisture	8,5-17% by weight
Incombustibles	8 % by weight
Heating Value	7.500 BTU/lb (ca. 4170 kcal/kg)
Source: [16] quoted in [8]	

Wet hazardous health-care waste in middle-income developing countries would have a low heating value of 3500kcal/kg (14.65MJ/kg) [1].

General-HCW has the following approximate chemical composition:

- 50% carbon
- 20% oxygen
- 6% hydrogen
- numerous other elements.[1]

In this context the employment of *halogenated* plastics (such as polyvinyl chloride) should be avoided, because of environmental relevant aspects especially if waste is incinerated. The identification of halogenated plastics is partially possible on the basis of internationally recognised symbols.

1.2 Health impacts of health-care waste

The specific hazard potential of HCW defines itself by the kind of the waste and by handling this. Depending upon activity and role of the persons in health-care facilities these are differently endangered. This section addresses the potential hazards of exposure to HCRW.

1.2.1 Hazards of health-care waste

In some low-income developing countries the completely health-care waste is handled as municipal waste stream and cause public health, staff health and environmental impacts. However, awareness of the potential and actual problems of handling and disposal of HCW is now increasing (see [4] and [17]).

1.2.1.1 Types of risks, pathways and hazards

Hazardous HCW has one or more of the following characteristics:

- it contains infectious agents,
- it is genotoxic,
- it contains toxic or hazardous chemicals or pharmaceuticals,
- it contains sharp items. [4]

The type of hazard, which proceeds from HCW, is directly dependent of the respective hazardous characteristic of the waste. Tab 21 outlines the risks that may be posed by health-care waste and the associated pathways and hazards.

Tab 22 Risks, pathways and hazards of HCW

Risk	Pathway	Hazard
Contraction of disease/infection	Direct or indirect contact through a carrier	Infectious wastes may transmit disease and infection through direct contact or via vectors
Cuts	Direct contact	Sharp waste including syringes, glass and scalpels may cause cuts which provide an entry into the body for infection: for example, used syringes may be recycled by unscrupulous medical practitioners, or played with by children and are potential transmission routes for HIV and Hepatitis B

Ineffective medical care	Direct contact	Consumption of expired pharmaceuticals possibly through inappropriate prescription by unscrupulous medical practitioners
Cancer	Direct or indirect contact, or proximity to waste	Radioactive waste
Burns and skin irritation	Direct or indirect contact, proximity to waste	Toxic chemicals Radioactive waste
Injury from explosion	Being within the vicinity when explosion occurs	Pressurised containers
Pollution of groundwater, surface water and the air	Direct or indirect contact with polluted water or release to the atmosphere	Toxic chemical wastes Pharmaceuticals Waste with high heavy metal content
Source: [18]		

1.2.1.2 Persons at risk

The impacts of poor HCWM differ from one person group to another. Persons who come directly into contact with HCW, including those within HCFs that generate hazardous waste and those outside the sources who either handle such waste, are particularly at risk.

Persons at risk are:

- medical doctors, nurses, health-care auxiliaries, and hospital maintenance personnel;
- patients in health-care establishments or receiving home care;
- visitors to health-care establishments;
- workers in support services allied to health-care establishments, such as laundries, waste handling, and transportation;
- workers in waste disposal facilities, including scavengers. [1]

In developing countries impacts result mostly from direct contact with waste as a consequence of poor HCWM practices. Then the *informal* actors are most at risk. Tab 23 shows the risks to this person group.

Tab 23 Risks to informal actors

Person group	Risk Level	Why

Waste pickers	Very High	Close and direct contact with waste. No alternative method of income generation - HCW often provides greater economic return than other waste. Low level of education and low awareness of risks. Little use of protective equipment due to cost, low awareness and the fact that it hinders their work. Often low resistance to disease and infections due to poor diet and poor living conditions. Poor access to health-care. More likely to use unscrupulous doctors and be affected by the primary recycling of products. Residential areas likely to be near/on waste sites. Contamination of living environment.
Recycling industry: • Itinerant waste buyers • Middle dealers • Main dealers	High	Close contact with waste but less than waste pickers. Exposure to by-products from waste processing. No alternative - livelihood depends on contact with waste. Low level of education and low awareness of risks. Little use of protective equipment due to cost, low awareness and it often hinders their work. Often low resistance to disease and infections due to poor diet, poor living conditions etc. but usually have higher income and quality of life than waste pickers. Poor access to health-care. Likely to use unscrupulous doctors and be affected by the primary recycling of health-care products. Contamination of environment
Source: [18]		

Informal actors usually act on an independent basis and may from small micro-enterprises. They are outcasts of society, come from very poor backgrounds, have small education and their opinions are rarely considered. The income is largely dependent on their personal day to day activities/work patterns and good fortune. The collection of waste represents the only income acquisition.

The *formal* sector and the local community are far less endangered (see the next two tables).

Tab 24 Risks to formal actors

Person group	Risk Level	Why

Health-care workers	Medium	Highest awareness of dangers. May have undergone training in best practices therefore more likely to apply these routines. Involved in creation of waste but have little contact with waste after its generation i.e. are usually not involved with waste collection. If working within HCF may be provided with free health-care and likely to be immunised against certain diseases that can be transmitted through waste. Contamination of living environment
Health-care waste workers Sweepers in hospitals other low grade hospital staff	High	Some awareness of dangers as may have undergone training in best practices. Often supplied with protective equipment but may be reluctant to use it. Relatively high level of contact with waste. If working within HCF may be provided with free health-care and likely to be immunised against certain diseases that can be transmitted through waste. Contamination of environment.
Municipal waste workers	High	If co-disposal practised may come in close contact with HCW. Low awareness of dangers - reluctance to use protective equipment even if provided. May not be aware that they are in contact with HCW. Often also involved in waste picking activities. Close/direct contact with waste. Higher/more stable income than waste pickers therefore higher quality of life, access to health-care. Contamination of environment
Source: [18]		

Tab 25 Risks to public community

Person group	**Risk Level**	**Why**

Low-income groups	Medium to High	Residential areas likely to be near/on waste sites. Closer contact with waste than higher income groups, e.g. through vectors, contact with waste pickers. Little access to health-care. Likely to use unscrupulous doctors and be affected by the primary recycling of health-care products. Low level of education and low awareness of risks. Often low resistance to disease and infections due to poor diet, poor living conditions etc. Contamination of environment.
Children	High	Low awareness of dangers. Attraction to parts of waste e.g. syringes as toys. At more risk if from low-income families as likely to have greater access to waste due to location & lack of supervision. Likely to have a lower resistance to disease and infection than adults. Contamination of environment.
Drug addicts	High	Exposed to similar risks as waste pickers as they scavenge for used hypodermic needles and syringes to use to inject drugs. May attempt to use (misuse) drugs found on health-care waste sites. If from low-income groups, also subject to the above risks.
Health establishment visitors & patients	Medium	Where HCWM practices are poor, they may be exposed to waste. Visitors less at risk than patients as shorter stay and have greater resistance to infection. Contamination of environment
Middle-high income groups	Low	Little or no contact with waste or with waste workers. Good living conditions and access to good health-care. Contamination of environment. Greater political power to stop bad practices occurring near homes. Higher level of education and greater awareness of risks
Source: [18]		

Health-care waste may be provided with protective equipment and receive basic training, although in low-income countries this is frequently neglected. They will have a higher level of general education and their education status is much higher than scavengers. A basic knowledge of health-care waste practices is present.

Very low-income families may live in squatter settlements or even within a waste dump. The education, the income and the quality of life are by far not as high as with high-income groups. They are usually poorly educated and their opinions are often neglected. [18]

In industrialised countries with a high standard of waste management the situation presents differently. Therefore the group most at risk are patients and medical care workers, especially nurses, followed by other hospital workers and by waste management operators outside the hospital. Tab 26 assesses the risk of infection by the different categories of waste for different person groups at a well minted waste management.

Tab 26 Risk of infection according to different categories of HCW

Category of HCW	**Patients**	**Medical care workers**	**Other persons (e.g. employees of locally waste feeder)**
General waste, such as packing materials (cardboard boxes, plastic packing, glass …)	no	no	no
General waste, contaminated with facultative pathogenic infection exciters	yes	no	no
Infectious waste, contaminated with obligate pathogenic infection exciters	yes	yes	yes
Source: Own representation, in imitation of [19]			

1.2.1.3 Hazards from infectious waste and sharps

Infectious agents in waste may enter the human body by a number of pathways:

- through a puncture, abrasion, or cut in the skin;
- through the mucous membranes;
- by inhalation;
- by ingestion. [4]

Tab 27 Examples of infectious diseases according to transmission pathways are differentiated and listed in Tab 27. The table indicates the significant infectious body fluids and/or secretion. Examples of diseases of humans with those infectious waste can result

Transmission path	**Exciter**	**Infectious secretion / body fluid**
More directly contact with skin or	HIV	Blood
	Viral hepatitis	Blood and body fluids

mucous membrane of injury	TSE (transmissible spongiform encephalopathy)	Tissue, *cerebro-spinal fluid*
	CJD Creutzfeld-Jakob disease	Tissue, cerebro-spinal fluid
Smear infection	Cholera	Stool, vomit
	Dysentery	Stool
	Epidemic typhus, paratyphoid fever	Stool, urine, biles, blood
Aerogen/ airborne-; smear infection (human-pathogenic)	Unarrested tuberculosis	*sputum*, urine, stool
	Meningitis / encephalitis	Sputum / faucal secretion
	Diphtheria	Sputum / faucal secretion, ichor
	Leprosy	Nasal discharge, ichor
	Anthrax	Sputum / faucal secretion, ichor
	Pest	Sputum / faucal secretion, ichor
	Pox	Faucal secretion, secretion by pustule
	Poliomyelitis	Sputum / faucal secretion, stool
	Glanders	Sputum / faucal secretion, ichor
	Rabies	Sputum / faucal secretion
	Rabbit fever	Ichor, sanies
	Haemorrhagic fevers (Junin, Lassa, Ebola, and Marburg viruses)	All bloody products and secretions
Source of contents: [20]		

In developing countries have particularly infections with human immunodeficiency virus (HIV) and hepatitis viruses B and C a great importance. These infectious diseases can be transmitted after contact with HCW through injuries from syringe needles contaminated by human blood.

A further large HCWM-problem is the existence of bacteria resistant to antibiotics and chemical disinfectants. These bacteria can occur in HCW and may also contribute to the hazards created by poorly managed health-care waste. Plasmids from laboratory strains contained in HCW can be transferred to indigenous bacteria via the waste disposal system. [4]

Contaminated sharps (particularly hypodermic needles) and concentrated cultures of pathogens from research and/or diagnostic units are probably the waste items that represent the most acute potential hazards to health. [4]

Sharps may not only cause cuts and punctures, but also infect the wounds by agents that previously contaminated the sharps. Due to this double risk -of injury and disease transmission- sharps are considered as a highly hazardous waste class. Infections that may be transmitted by subcutaneous introduction of the agent, e.g. viral blood infections, are the main diseases of concern. Hypodermic needles are often contaminated with patients blood and are thus particularly hazardous.

However, the probability of infection caused by HCW is marginal, if appropriate preventative measures and personal hygienic measures are in progress. More than one pre-conditions must be complied to lead to disease outbreaks. It is about chain of reaction and the passage of every “element” is necessary to cause a disease. The elements are:

- contact with HCW,
- injury (either pre-existing or resulting by contact with HCW), that enables the entry of pathogens,
- transference of a sufficient number of germs on a receptive individual via this entry,
- the infection,
- the outbreak of disease [21].

Following figure shows the chain of reaction starting from the contact and the injury with all elements necessary.

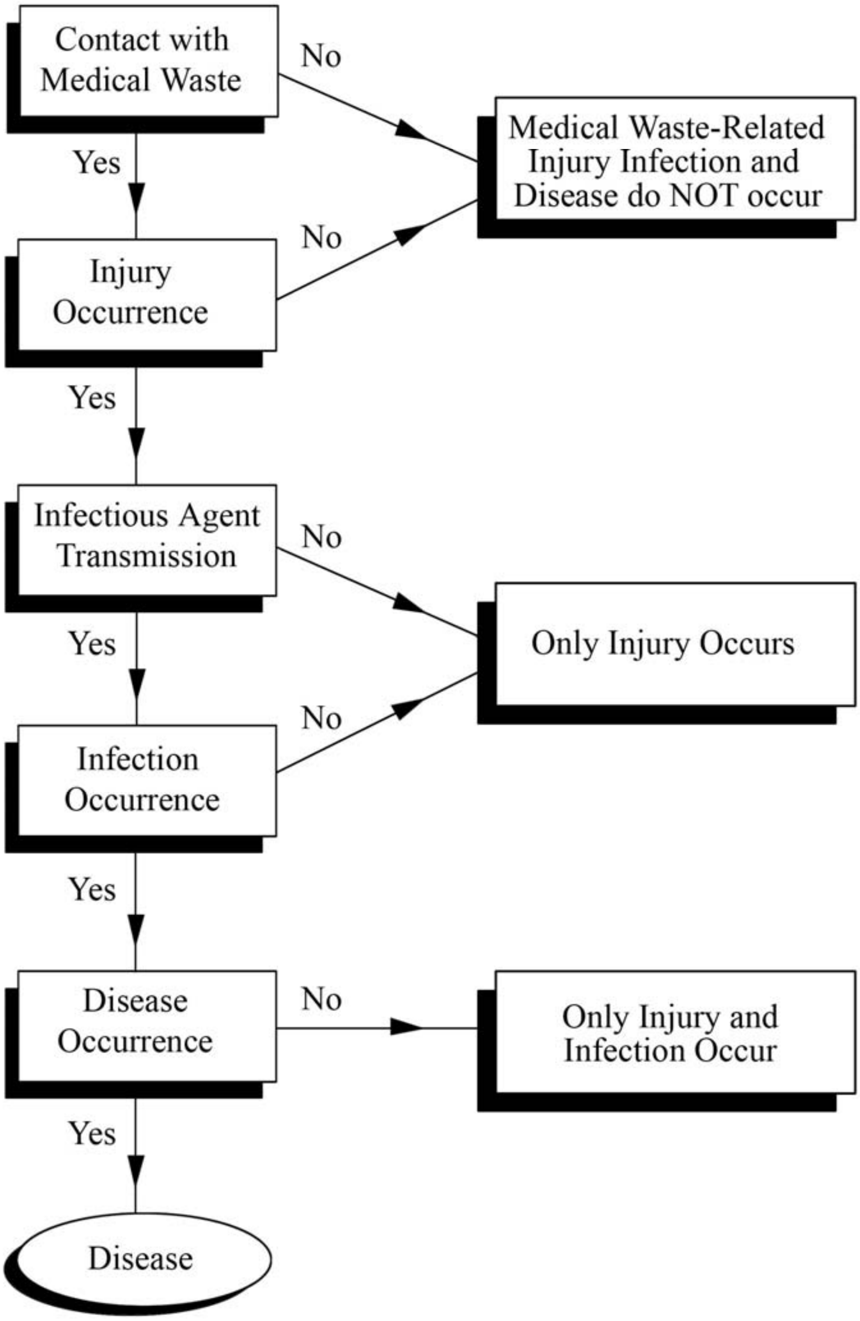

Abb. 1 Chain of reaction leading to disease caused by HCW

1.2.1.4 Hazards from chemical and pharmaceutical waste

Chemicals and pharmaceuticals used in HCFs contain flammable, corrosive, toxic, reactive, explosive, shock sensitive, cyto- or genotoxic properties. Therefore, they may cause toxic effects (acute or by chronic) and injuries, including burns. These substances are commonly present in small quantities in health-care waste; larger quantities may be found when outdated or unwanted chemicals and pharmaceuticals are disposed of. [1]

Toxic effects can result from absorption of the chemicals or pharmaceuticals through/from:

- skin,
- mucous membranes,
- inhalation or
- ingestion.

Tab 28 Listing of hazardous chemicals in HCW and their risks

Hazardous chemical	Range of application and/or examples	Risks
Formaldehyde	Conservation agent in the pathology	Toxic, carcinogenic
Photographic developer- and fixing baths	Development of radiographic films	Toxic
Solvents and chemical cleaner	Laboratory, general clean-up	Carcinogenic, impairment of blood content, corrosive
Mercury	Crashed thermometer	Intoxications, mutagenic
Explosive and flammable substances	Dry cleaning spirit, alcohol, industrial gases	Danger of explosion, fire, toxic vapour
Toxicants, expired pharmaceuticals	Pharmacy	Intoxications
Corrosive substances, various chemicals	Alkaline, acids, lab chemicals, cleaner	Chemical burn, intoxications, carcinogenic
Source of contents: [3]		

Injuries can be caused by contact with flammable, corrosive or re-active chemicals with the skin, the eyes or the mucous membrane of the lung. The most common injuries are burns. [1]

Chemicals used in large quantities are disinfectants. This sub-group is often corrosive. Particularly with the disposal should be noted that reactive chemicals may form high toxic compounds.

Some chemicals such as obsolete pesticides can directly or indirectly affect the health of someone who comes into contact with them. Pesticides, stored in leaking drums or torn bags, can contaminate the groundwater and thus the public health negatively affect. Beside the direct contact with the product, inhalation of vapours, drinking of contaminated water, or eating of contaminated food, hazards may result of inadequate disposal.

Chemical residues discharged into the sewage system may have toxic effects on the natural ecosystems of receiving waters or on the operation of biological sewage treatment plants (see Tab 29). Therefore, large quantities of chemicals, particularly disinfectants, should not be discharged into a sewerage system or watercourse.

Pharmaceutical residues may have similar effects, as they may include antibiotics and other drugs, heavy metals such as mercury, phenols and derivatives and other disinfectants and antiseptics. [1]

Note: Packaging, storage and disposal of pharmaceuticals should be secure. In some countries expired pharmaceuticals may come into the hands of scavengers and children if waste is disposed in an open dump. Pharmaceuticals can be pilfered from a stockpile of waste drugs or during sorting. These drugs may be diverted to the market for resale and misuse.

Metallic mercury evaporated already at room temperature and can enrich itself in the room air. Taken up by inhalation it can lead then to intoxication. Therefore, Mercury remainders must be more always completely removed. Free mercury can be bound with special absorber means.

Tab 29 Damage of sewage treatment plant bacteria by active substances of disinfectants (oxygen sag test)

Active Substance	Limit value concentration (ppm)
Formaldehyde	30
Glyoxal	500
Glutaraldehyde	130
Ethyl alcohol	> 100
N-propanol	> 100
Isopropanol	> 100
Peracetic acid	90
Source: [27]	

1.2.1.5 Hazards from genotoxic waste

Personnel involved in delivery, transport, and disposal of cytostatic drugs may be affected, as well as technical and laboratory staff (for example during maintenance of safety cabinets or the analysis of patient blood or urine).The severity of hazards for health care workers handling cytotoxic waste is the combined effect of the substance toxicity and of the magnitude of exposure.

Exposure to cytotoxic substances in health care may also occur during preparation for treatment. Main pathways of exposure are inhalation of aerosols or dust, skin absorption, and ingestion of food accidentally in contact with cytotoxic drugs. In addition impacts result from contact with chemotherapy patient’s body fluids and secretions.

Cytotoxic drugs may cause dermatitis, dizziness, nausea, or headache. The most cytotoxic drugs are irritants and have harmful local effects after direct contact with skin or eyes. [1]

The evidence of an increased health risk from improper work practices is suggested in the literature. For example, the occurrence of side effects, such as nausea and eyelash loss in nursing personnel, has been reported by [28]. In several studies cytostatic drugs were detected in the urine of pharmacy and nursing staff ([29], [30]).

Any discharge of such waste into the environment could have disastrous ecological consequences for the environment. Such substances must be either destroyed by high temperature incineration (or stored in sealed containers). Only small quantities can be inactivated by other chemical substances.

1.2.1.6 Hazards from radioactive waste

The type of disease caused by radioactive waste can range from headache, dizziness, and vomiting to much more serious problems. Radioactive waste is genotoxic and therefore it may affect genetic material. Handling of highly active sources should be undertaken with the utmost care. It may cause much more severe injuries, such as destruction of tissue. [1]

Low-activity radioactive waste may cause minor hazards, such as contamination of external surfaces of containers. However, health-care workers, waste-handling or cleaning personnel exposed to this radioactivity are at risk.

1.2.2 Public health impacts of health-care waste

1.2.2.1 Impacts of infectious waste and sharps

The group most at risk are health-care workers, especially nurses, followed by other hospital workers and by waste management operators outside the hospital. In developing countries scavengers, who scavenge HCW on waste disposal sites are at significant risk. However, in this connection meaningful data are not present.

In some countries (e.g., India) the practice of scavenging, repackaging and reuse of contaminated disposable needles without *sterilisation* is disseminated. This practice is associated with serious health implications. An extensive investigation estimates that the reuse of non-sterile needles causes globally 22,5 million hepatitis B infections (35% of new cases) per year, 2,7 million hepatitis C infections (55% of new cases) per year, and 98.000 HIV infections (2% of new cases) per year [22]. Other infectious diseases possibly transmitted by non-sterile syringes include lassa fever, Ebola fever and malaria [23]. Based on this and other studies ([24],[25]), a person receiving one needle stick injury from a contaminated sharp used on an infected patient has a probability of 30% of being infected by Hepatitis B, 1,8% of being infected by Hepatitis C and 0,3% of being infected by HIV.

Note: The difference between the probabilities is justified by the different survivability of the viruses. HIV has an extremely limited viability outside a living host. It survives only 3-7 days at ambient temperature and is inactivated at 56 °C [1]. By contrast, HBV is very persistent in dry air and can survive for several weeks on a surface. Therefore, the potential for Hepatitis B infection following contact with HCW is likely to be higher than that associated with HIV, except for those persons within the health-care setting.

The annually overall on-the-job injury rate of sanitary services workers is 180 per 1.000 workers. [26]

Ranges of HCW related injuries from sharps occurring annually for health-care and sanitary service personnel estimated by the US Agency for Toxic Substances and Diseases Register (ATSDR) in their report to Congress on medical waste are summarised in following table. A lot of injuries are caused by recapping of hypodermic needles before disposal into containers, by the use of materials that are not puncture-proof for construction of containers or by unnecessary opening of these containers. [1]

Tab 30 Viral hepatitis B infections caused by occupational injuries from sharps (USA)

Professional category	Annual number of people injured by sharps	Annual number of HBV infections caused by injury
Nurses		
• within hospitals	17.700 – 22.200	56 – 96
• outside hospitals	28.000 – 48.000	26 - 45
Hospital laboratory workers	800 - 7.500	2 - 15
Hospital housekeepers	11.700 - 45.300	23 - 91
Hospital technicians	12.200	24
Physicians and dentists in hospital	100 - 400	< 1
Physicians outside hospital	500 – 1.700	1 - 3
Dentists outside hospital	100 - 300	< 1
Dental assistants outside hospital	2.600 - 3.900	5 - 8
Emergency medical personnel (outside hospital)	12.000	24
Waste workers (outside hospital)	500 - 7.300	1 - 5
Sources: [1], [26]		

It is suspected that many cases of infection in developing countries with a wide variety of pathogens have resulted from exposure to improperly managed HCW. [1]

The annual number of Hepatitis B infections in the USA resulting from exposure to HCW is between 162 and 321, out of an overall yearly total of 300.000 cases. [1]

In June 1994, 39 cases of HIV infection in the USA were recognised by the Centres for Disease Control and Prevention as occupational infections, with following pathways of transmission:

- 32 from hypodermic needle injuries
- 1 from blade injury
- 1 from glass injury (broken glass from a tube containing infected blood)
- 1 from contact with non-sharp infectious item
- 4 from exposure of skin or mucous membranes to infected blood. [1]

It is recommended that all personnel handling HCW should be immunised against the disease. A vaccine against viral hepatitis C is not available at present.

It becomes clear that in developing countries injuries and infections while handling waste are to be particularly avoided only by supervision and training as well as by a well working comprehensive waste management.

1.2.2.2 Impacts of chemical and pharmaceutical waste

Persons at risk are pharmacists, anaesthetists, and nursing, auxiliary, and maintenance personnel. Substances such as vapours, aerosols, and liquids may cause respiratory or dermal diseases. To minimise risks, less hazardous chemicals should be substituted whenever possible. While handling of hazardous chemicals protective equipment should be provided and personnel at risk should be well trained. Locations where hazardous chemicals are used should be properly ventilated. [1]

Founded investigations on the spreading of diseases due to chemical or pharmaceutical waste from HCFs are not present right now. However, many examples may be found of extensive intoxication caused by industrial chemical waste and it is certain that many cases of injury or intoxication result from a messy handling of chemicals or pharmaceuticals in HCFs. [1]

1.2.2.3 Impacts of genotoxic waste

The assessing human exposure to genotoxic waste is difficult. Therefore, data on the long-term health impacts of genotoxic health-care waste are rare.

Residues of cytostatic drugs in drinking water has not been documented by now. However, the entry of cytotoxic substances into the environment should be minimised. [31]

The significant correlation between fetal loss and occupational exposure to *antineoplastic* drugs during the first three months of pregnancy was found by a study undertaken in Finland. Studies in France and the USA failed to confirm this result. [1]

The concentrations in patient excretions are so small that based on present knowledge, a hazard for human health and the environment is unlikely [31]. Other studies had as result that in exposed workers urinary levels of mutagenic compounds increased and the risk of abortion increased. The concentration of cytotoxic drugs in the air inside hospitals has been examined in some studies designed to evaluate health risks linked to such exposure. [1]

1.2.2.4 Impacts of radioactive waste

In a Brazilian city radioactive hospital wastes caused a notorious accident in 1989. There were fatal and other serious cases of irradiation by radioactive HCW in abandoned equipment that was scavenged from a dump [26]. As a consequence, 249 people were exposed, of whom several either died or suffered severe health problems [1].

Apart from the described incident, no reliable scientific data are available on the impact of radioactive HCW. It doesn’t mean that exposure to radioactive HCW doesn’t exist but many cases go unreported. The only recorded accidents have resulted from unsafe operation of X-ray apparatus, improper handling of radiotherapy solutions, or inadequate control of radiotherapy. [1]

1.2.3 Pathogenic microorganisms in the environment and concentration in HCW

The ability to survive in the environment is limited and is very specific to each microorganism and is a function of its resistance to environmental conditions [1]. The main limiting factors are:

- temperature,
- pH-value,
- humidity,
- ultraviolet irradiation,
- availability of organic substrate material.

The public interest implicated with diseases caused by HCW is directed to viral infections, in particular AIDS and Hepatitis B. The hepatitis B virus can survive for several weeks on a surface and is resistant to brief exposure to boiling water. An investigation in Japan sources that an infective dose of hepatitis B or C virus can survive for up to a week in a blood droplet trapped inside a hypodermic needle. [1]

The virus (HIV) causing AIDS is much less resistant. It survives for no more than 15 minutes when exposed to 70% ethanol and only up to 7 days at ambient temperature. The inactivation temperatures for HIV constitutes 56 °C. [1]

Most of pathogenic bacteria are less resistant than viruses. Exceptions are *prion*s and agents of degenerative neurological diseases (e.g. Creutzfeldt-Jakob disease), which seem to be very resistant.

Several studies investigated the microbial load of health-care waste (with the exception of waste containing pathogenic cultures) and arrives at the conclusion that the load of HCW is generally not very high. In fact, the concentration of indicator microorganisms in health-care waste similar domestic waste is generally no higher than in domestic waste. Following table circumstantiates this fact with values determinated in Germany. The investigations comprehended specimens of HCW with a similar composition like domestic waste. Medical soft waste, such as swabs and dressings were included.

Tab 31 Arithmetic values of germ counts for selected germ groups

Type of facility / unit	Overall germ count (CFU/g waste)	Gram-negative rods (CFU/g waste)	Group D streptococci (CFU/g waste)	Fungi, yeasts (CFU/g waste)
Major hospital				
Surgical intensive care unit	$1{,}48 \times 10^{6}$	$1{,}07 \times 10^{5}$	$4{,}37 \times 10^{3}$	$2{,}34 \times 10^{3}$
Surgical care unit	$6{,}31 \times 10^{6}$	$1{,}78 \times 10^{6}$	$2{,}88 \times 10^{5}$	$2{,}82 \times 10^{3}$
Internal intensive care unit	$1{,}23 \times 10^{6}$	$5{,}62 \times 10^{4}$	$1{,}82 \times 10^{4}$	$5{,}62 \times 10^{3}$
Internal care unit	$8{,}51 \times 10^{6}$	$1{,}15 \times 10^{6}$	$8{,}32 \times 10^{4}$	$1{,}15 \times 10^{2}$
Child care unit	$5{,}89 * 10^{7}$	$6{,}92 \times 10^{6}$	$1{,}32 \times 10^{6}$	$1{,}78 \times 10^{3}$
Area of operative procedures	$6{,}31 \times 10^{5}$	$1{,}32 \times 10^{4}$	$6{,}92 \times 10^{3}$	$8{,}13 \times 10^{2}$
Cottage hospital				
Surgical intensive care unit	$7{,}41 \times 10^{5}$	$2{,}40 \times 10^{4}$	$1{,}51 \times 10^{4}$	$8{,}13 \times 10^{2}$
Surgical care unit	$1{,}78 * 10^{7}$	$1{,}66 \times 10^{6}$	$6{,}17 \times 10^{5}$	$8{,}32 \times 10^{3}$
Internal care unit	$2{,}69 \times 10^{6}$	$1{,}41 \times 10^{6}$	$5{,}50 \times 10^{4}$	$7{,}94 \times 10^{3}$
Area of operative procedures	$2{,}88 \times 10^{4}$	$8{,}51 \times 10^{3}$	$2{,}75 \times 10^{2}$	$2{,}52 \times 10^{3}$
Domestic	$3{,}02 \times 10^{8}$	$6{,}31 \times 10^{7}$	$6{,}92 \times 10^{2}$	$6{,}46 \times 10^{7}$

waste				
Source: [32]				

The microbial load of waste generated by sensitive areas, such as operation theatres or intensive care units, is considerably lower than of waste generated in normal care units. The reason for the lower microbial load of HCW compared to domestic waste could be the higher hygienic standard in HCFs and the frequently occurrence of antiseptics in HCW.

1.3 Legislative, regulatory, and policy aspects

1.3.1 International agreements and regulatory principles

The environmental protection has in many developing countries a small priority so far than the daily fight around surviving or measures of the economy recovery. Therefore only few developing countries have appropriate laws and/or regulations regarding the waste management in the health service.

National legislation and regulations governing public health or safe management of hazardous waste should agree with international agreements compiled and published by multilateral organizations and/or combinations. The most important international agreement including the topic of HCW is the Basel Convention.

1.3.1.1 Basel Convention

The Basel Convention on the control of transboundary movements of hazardous wastes and their disposal enacted on May 5th 1992. Annex 1 of the Basel Convention contains the following waste categories resulting particularly in HCFs:

- Clinical wastes from medical care in hospitals, medical centers and clinics (Y1),
- Wastes from the production and preparation of pharmaceutical products (Y2),
- Waste pharmaceuticals, drugs and medicines (Y3),
- Waste from the production, formulation and use of biocides and phytopharmaceuticals (Y4).

By the end of 1999 inked the convention 131 countries as well as the European Union. This environmental agreement obligates the signing governments:

- to restrict the transboundary movements of hazardous wastes,
- to perform an environmentally sound disposal and treatment close at the point of origin and
- to reduce amount and degree of exposure of waste incurred already at the source.

Export, import and transit of wastes are legally allowed only after previously information and obtainment of the consent of all involved countries. Exported waste should always be labelled according to the UN recommended standards. The off-site disposal of wastes in non-contracting states is principle prohibited.

The convention is a basis for the definition of hazardous wastes and their transboundary movement in many developing countries.

1.3.1.2 International Atomic Energy Agency (IAEA)

The United Nations institutionalised the IAEA as an autonomous intergovernmental organization to provide advice to member states on nuclear power development, health and safety, radioactive waste management, legal aspects of atomic energy, and prospecting for and exploiting nuclear raw materials. The organisation has also been promoting efforts to establish standards for safe handling of hazardous waste substances. Thereby, the developing safety standards in the area of pre-disposal of hazardous wastes come to the fore, which includes collection, handling, treatment, conditioning, and storage of radioactive waste.

1.3.1.3 Regulatory principles

Different principles should be considered and taken in the national legislation relative the waste management:

Duty of care: Any person managing or handling hazardous substances is ethically responsible for using the utmost care in that task.

The polluter pays: All producers of waste are financially and legally responsible for the safe and environmentally sound disposal of the waste they produce.

The precautionary principle: When the magnitude of a particular risk is unknown, it should be assumed that this risk is significant. Measures to protect health and environmental should be designed accordingly.

The proximity principle: The treatment and disposal of hazardous waste should be took place at the closest possible location to its source in order to minimize the risks involved in hazardous waste transport. HCFs should dispose of or recycle waste inside its own territorial limits.

1.3.2 National Regulatory

The basis for the conversion of well function health-care waste practices are national regulatory. These are to obey of health-care facilities and centralised treatment and disposal facilities. Besides, national regulatory makes possible to establish legal controls. With the draft of regulatory different government institutions should be involved, particularly:

- the ministry of health and
- the ministry of environment or the national environmental protection agency [33].

Their competencies should be clearly defined before the law is enacted.

The following items are to be incorporate pertaining to contents:

- clear HCW classification, including a clear definition of hazardous HCW and of its various categories;
- a precise indications of legal obligations for HCFs, municipal waste managers, and disposal facilities;
- specifications for record-keeping and reporting and for an inspection system to ensure enforcement of the law, and for penalties to be imposed for contravention; and
- delegation of legal courts to handle disputes. [33], [34]

Apart from the waste-specific legal framework further regulations can be legally effective for the waste management in the health service:

- prevention and control of infectious disease regulations;
- regulations on environmental and health impact assessments;
- environmental emissions standards;
- regulations on management and disposal of radioactive materials; and
- emergency special procedures. [33], [34]

Not only to developing countries applies: Special regulations developed in conjunction with a national health-care strategy may have essentially the same effect as laws but may be implemented faster than these.

Particularly in developing countries the following schedule for compliance of the regulations is recommended: Hospitals with a high level of resources first, such as university hospitals, then smaller hospitals, and then smaller HCFs, such as first aid dispensaries. Thus the different levels of resources available are considered. Smaller HCFs may need more time to conform to the new regulations. [34]

Anyone involved in the production, handling, treatment or disposal of HCW has a general “duty of care”, i.e. an obligation to ensure that waste handling and associated documentation comply with national regulatory and/or laws.

1.3.3 Policy documents, guidelines and standards

The policy framework surrounding HCWM including policy documents, guidelines and standards is often necessary to implement the national regulations and/or law. Specific financial resources, locally available technology and maintenance, the state of training of the staff as well as cultural and religious aspects should be considered during the drawing up of the policy framework.

The policy document should contain the rationale for the legislation, plus national goals and the key steps essential to the achievement of these goals. Subjects of contents of the document may be:

- descriptions of the health and safety risks resulting from mismanagement of HCW;
- listing of approved methods of treatment and disposal for each waste category;
- reasons for sound and safe HCWM practices in HCFs;
- management responsibilities within and outside HCFs;
- warning against unsafe practices, such as disposing of hazardous health-care waste in municipal landfills;
- assessment of the costs of HCWM;
- key steps of HCWM: minimization, separation, identification, handling, treatment, and final disposal of waste;
- record-keeping and documentation;
- training requirements;
- rules governing the protection of workers´ health and safety. [33]

Technical, environmental and ethical guidelines should specify regulations on waste treatment (particularly for infectious waste), segregation, collection, storage, handling, disposal, and transport of waste, responsibilities, and training requirements. Law defaults, especially the definitions of health-care waste categories, are to be incorporated. Technical guidelines should be directly applicable and practical. The objective should be to ensure that safe practices are observed and appropriate standards achieved. [33]

They can be prepared by different governmental or nongovernmental bodies and/or interest groups, such as:

- a public health authority or environmental regulator,
- a professional associations or special interest groups
- an environmental group. [35]

Guidelines should include the following specifications:

- legal framework covering safe HCWM, hospital hygiene, and occupational health and safety;
- the responsibilities of public health authorities, (of the national environmental protection body, of the heads of health-care establishments, of the scattered and smaller producers of health-care waste; and of the heads of any private or public waste-disposal agencies involved);
- safe practices for waste minimization;
- separation, handling, storage, and transport of health-care waste;
- recommended treatment and disposal methods for each category of health-care waste and for wastewater. [33]

Standards are designed to protect consumers, employees, patients, or the environment. They may include exact specific instructions, which concern the safe handling of HCW, for example the maximum time health care waste can remain in storage before disposal. Experiences in practice show, that standards usually derive from current good practice and have a tremendous power to influence behaviour of managers and medical staff.

In a regulatory vacuum, is it meaningfully to use guidelines and standard published by internationally agencies such as the WHO and United Nations Environment Programme (UNEP) as starting point.

1.3.4 Local procedures

The developing of local procedures in effect for one larger HCF or small region is meaningful and simple, where no prescribed national regulations exist and also often necessary to implement national regulatory. In this manner primarily health-care and infection control staff should cooperate. They may draw up an own set of procedures in effect for all staff. These larger HCFs are thus pioneers for other smaller HCFs. Local procedures may result also by bilateral co-operation.

Locally prepared procedures should be simply understandable and fast readable. The practical instructions must be clearly and specifically formulated if necessary. The most effective types of guidance are those that are pictorially presented on a poster, or that use simple plain language on few sides of a sheet of paper. [35]

1.4 Health-care waste management planning

1.4.1 The require of planning

Risks inside and outside HCFs may be minimized by introducing a process of health care waste management (HCWM) planning within HCFs. HCWM includes planning and procurement, staff behaviour and training, proper disposal and treatment methods inside and outside the HCFs, evaluation, and proper use of tools. The avoidance of infection risk for patients, personnel and visitors should have a clear priority before waste-economical or financial considerations.

It is important to formulate objectives and to draft planning for their achievement to ensure continuity and clarity in HCWM. HCFs should develop clear plans including the definition of a strategy for the proper management and the environmentally compatible and health safety disposal of wastes. Necessary measures are to be implemented carefully in order to affect the motivation of authorities, health-care workers, and the public not negative and to define further actions that may be needed [33].

A strict conversion of the targets requires further integration into routine employee training, continuing education, and hospital management evaluation processes for systems and personnel.

In some countries municipal governments or state governments could require waste management plans from all hospitals as a condition for operating.

1.4.2 Agenda 21 as an international recommendation

The Agenda 21 is an international recommendation getting under way by the United Nations Conference on the Environment and Development (UNCED) in 1992, with the objective of a sustainable development. It is a guide for every nation and recommends among other targets a set of measures for waste management.

Chapter 20 of the Agenda 21 has the heading: “Environmentally sound management of hazardous wastes, including prevention of illegal international traffic in hazardous wastes”. It is also effective to the waste management in HCFs and disposal or treatment facilities.

The most important objective targets associated with the waste management may be summarized as follows:

- prevention and minimization of waste production,
- reusing or recycling of the waste to the possible extent,
- waste treatment by safe and environmentally sound methods,
- disposal of final residues (after incineration) by landfill in confined and carefully designed sites. [33]

Agenda 21 also includes regulatory principles, such as that any waste producer is responsible for the treatment and final disposal of its own waste. The disposal of waste should be accomplished within the boundaries of the respectively community. [33]

The objectives included in the agenda 21 should be in local level planning again.

1.4.3 National plans for health-care waste management

National management plans implement health-care waste management options on a national scale and identify actions on a district, regional, and national basis, taking into account conditions, needs, and possibilities at each level. An appropriate, safe, and cost-effective strategy is concerned principally with treatment, recycling, transport, and disposal options. [33]

A national programme of proper HCWM should be developed through a stepwise action plan. In the apron of the development of a management plan absolutely the individual types of waste are to be defined and are to be distinguished from each other as exactly as possible. The valid international legal basic conditions are to be considered.

The WHO recommends seven steps described in more detail in the following paragraphs [33]:

- Step 1: Establishment of policy commitment and responsibility for health-care waste management
- Step 2: Conduct of a national survey of health-care waste practices
- Step 3: Development of national guidelines
- Step 4: Development of a policy on regional and cooperative methods of HCWM
- Step 5: Legislation: regulations and standards for HCWM
- Step 6: Institution of a national training programme
- Step 7: Reviewing of the national HCWM programme after implementation.

A graphical representation of the recommended schedule of the stepwise development of national HCWM plans shows following figure. The round time need is stated in months (m).

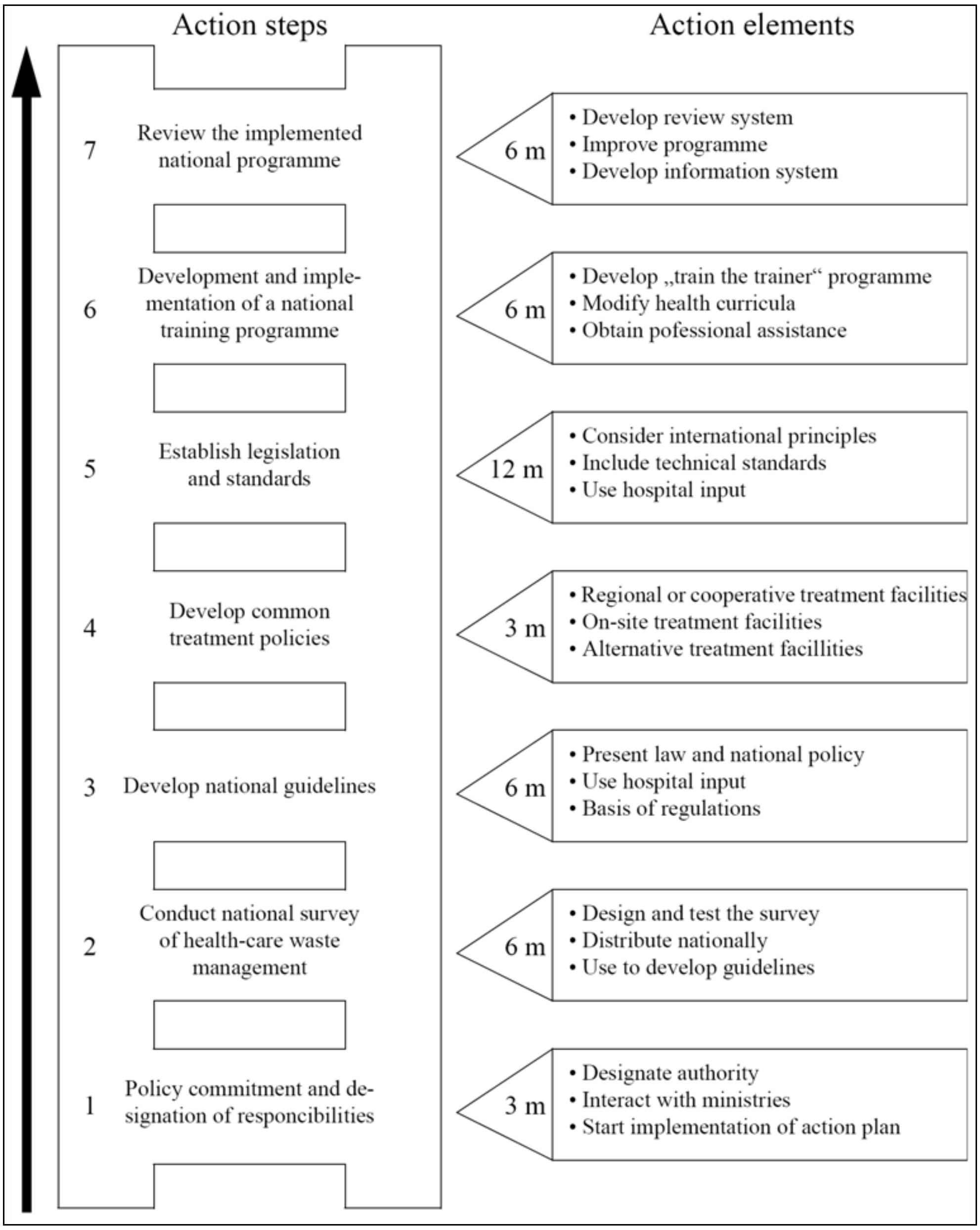

Abb. 2 Schedule for a national plan of HCWM

Step 1: Establishment of policy commitment and responsibility for health-care waste management

The draft of a national policy and the delegation of responsibility to the appropriate government authority have to precede of the implementation of a national plan. Different governmental authorities should work closely and cooperate with one another. The principle authority will be incumbent on the ministry of health or the ministry of environment. [33]

Governmental authorities should cooperate with the private sector, nongovernmental organisations (NGOs), and/or professional organisations at the implementation-phase of the national action plan. [33]

Guidance from governmental authorities should lead to maximum efficiency in the use of available resources from health-care establishments. [33]

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

It is necessary to fully aware of current levels of waste generation to establish an effective waste management programme. The essential data should be available to the national agency responsible for the disposal of health-care waste. In addition national waste management practices should be considered.

Basic data may be collected by means of wide-ranging questionnaire completed for all HCFs. The following data should to be recorded:

- number of hospital beds and bed occupancy rate for each HCFs;
- types and quantities of waste generated;
- personnel involved in the management of health-care waste;
- current HCW disposal practices, including segregation, collection, transportation (off-site and on-site), storage, and disposal methods. [33]

If more detailed information on types and quantities of waste generated are not at hand, can missing data also be determined roughly by empirical values from other HCFs.

An exemplary questionnaire to collect data about HCWM shows Abb. 3.

The survey should include site observations and interviews with employees (waste workers, cleaners, etc.). The information collected will provide a basis for formulating strategy for different levels (district, regional, and/or national). [33]

Questionnaire
for health-care waste management

Hospital:

name, location: ______________________________

type of facility:
- ☐ specialised
- ☐ university hospital
- ☐ district
- ☐ general
- ☐ regional
- ☐ ______________

Number of patients:
- inpatients: ________ / day
- outpatients: ________ / day

Included wards / units: total: ________

Types:
- ☐ general medicine
- ☐ operating theatre
- ☐ dialysis
- ☐ accident and emergency unit
- ☐ autopsy
- ☐ laboratory
- ☐ kitchen
- ☐ surgical ward
- ☐ intensive care
- ☐ oncology
- ☐ ambulance
- ☐ blood bank

Number of beds: total: ________ / day

including:
- ________ in ________________ - ward
- ________ in ________________ - ward
- ________ in ________________ - ward
- ________ in ________________ - ward
- ________ in ________________ - ward
- ________ in ________________ - ward

employees:

- Number of physicians: ______________
- Number of nursing staff: ______________
- Number of service staff: ______________

Abb. 3 Exemplary questionnaire to collect HCWM relating data

Step 3: Development of national guidelines

A national policy document and technical guidelines should be defined and formulated based on the results of the national survey. They should provide the technical foundation on which HCFs can build their individual management programmes. Both may be brought together in one comprehensive document. [33]

The content of technical guidelines and policy documents are outlined in section 1.3.3 “Policy documents, guidelines and standards“.

Step 4: Development of a policy on regional and cooperative methods of HCWM

Resources that will ensure a national network of disposal facilities for health-care waste should be identified by the designated governmental agency, as the further step. In this regard the concentration of the HCFs and the accessibility of the disposal facilities are relevant. Equipment involved in acceptable treatment options and technical specifications for the processes should be included also in a national or regional policy. [33]

Three options for organisation the treatment of HCW are to be differentiated:

- on-site treatment in each health-care establishment
- regional or cooperative health-care waste treatment, supplemented by individual facilities for outlying hospitals.
- treatment of HCW in existing industrial or municipal treatment facilities, where these exist. [33]

Regional circumstances, such as the number, position, type and size of HCFs, the quality of the road system and existing technical and financial resources should be considered. [33]

Each option has specific advantages and disadvantages. These are more near discussed in following curriculum “Treatment and disposal technologies of health-care waste”.

Step 5: Legislation: regulations and standards for HCWM

Legislation is necessary to regulate the application of the developed policy and guidelines. The basis should be international agreements, like mentioned already above. [33]

Step 6: Institution of a national training programme

The postulate to ensure a proper HCWM programme is the training of all managers and other involved personnel. Competent institutions or centres for the trainers programme should be identified and the central government should assist in preparation of “train the trainer” activities. [33]

The problematic nature of the training is more near regarded in chapter 10.

Step 7: Reviewing of the national HCWM programme after implementation

The national HCWM programme is in principle a continuous process. In addition, treatment methods are subject to new developments. Therefore a periodic monitoring and assessment by the responsible national government agency is necessary. [33]

The base of assessment is primarily the inquiry of data in the form of reports from HCFs and off-site waste treatment and/or disposal facilities. These should be made annually and be submitted by the heads to the national agency. In addition, the national agency should make random visits to carry out audits of the waste management systems. The results of the reports and the visits are to be implementing constantly in the waste management plan by the national agency. [33]

Among an identification of deficiencies, the heads of the facilities should be informed of potential recommendations for remedial measures. Concerning this matter, the time limit for implementation of remedial measures should be specified and the head of the HCFs should be informed of the follow-up date. [33]

1.4.4 Waste management plan for a health-care facility

Poor HCWM exposes patients, health-care workers, waste handlers and the community to toxic effects, infections and injuries. In addition, the general public associates poorly managed health-care waste with a poor standard of health-care [35].

Proper waste management in HCFs, no matter what size, should realise several objective targets:

- environment protection;
- cost reduction;
- waste minimization;
- optimisation of the recovery and recycling rates;
- prevention of public health impacts
    - decrease of infectious disease transmitted from dirty needles and other improperly cleaned/disposed medical items,
    - decrease of zooanthroponoses;
- concerns of the hygiene within HCFs
    - decrease of nosocomial diseases;
- reduction of the potential for occupational accidents.

The introducing of planning is essential to initiate a sustainable new HCWM system or to improve an existing HCWM system or in HCFs based on national guidelines. The implementing of specified issues and the optimizing of existing HCWM systems are possible only by use of a holistic and efficient waste management plan. Especially in major HCFs it is thereby important to take multi-focus aspects into the consideration, such as the purchase and logistics.

The planning of HCWM should not only cover technical aspects related to waste management, such as waste handling, storage, transportation, treatment and disposal, but also financial aspects, human resources development, staff responsibilities and roles, surveillance and control. By means of a development of a waste management plan it should be possible for staff and managers to address improvements in HCWM activities. [36]

Important starting points for proper HCWM planning are the knowledge of waste generation, generation points and the individual cost structure. Only with these values objectives, such as waste minimization, reuse and recycling, and cost reduction, can be converted.

By the planning and in the implementation of HCWM it is important to be closely in relationship with other HCFs, waste disposal contractors, and institutions and national authorities and agencies, which constitute the major components of a national HCWM system. Only thereby it is possible to avoid subsequent adjustments in the HCWM system, which may cause additional expenses. In addition, a closely relationship facilitates the co-operation, also during possibly encountered problems.

A HCWM plan should be developed stepwise, like a national programme of HCWM, and should be implemented from the onset of planning a HCF to avoid expensive rectifications. If legal national regulations regarding waste classification are not available, own regulations regarding the classification are to be provided by the HCFs in apron, as it is an important basis for a proper HCWM within HCFs. If necessary, existing national regulations are to be adapted to the circumstances or are to be completed exactly if necessary.

The WHO [1] advises six steps to develop a waste management plan for a HCF:

- Step 1: Designation of responsibilities,
- Step2: Accomplishment of a HCWM survey and invitation to suggestions,
- Step 3: Recommendation of HCWM improvements and preparation of a set of arrangements for their implementation,
- Step 4: Draft of the HCWM plan,
- Step 5: Approval of the HCWM plan and start of the implementation,
- Step 6: Review of the HCWM plan.

Step 1: Designation of responsibilities

The basis of an efficient HCWM within HCFs is the designation of responsibilities. The HCWM structure and the responsibilities, roles and duties concerning this matter should be defined as accurately as possible within the management plan [36]. In addition lines of accountability should be established. At the selection of the responsible persons their occupational and technical suitability are to be considered. If possible highly responsible functions should be filled by persons with a science or engineering education. Particularly in smaller HCFs can be fallen back to the already available relevant staff and one individual may fulfil two or more sets of responsibilities [33]. In larger HCFs with great distances between the departments it can be necessary to define several but similar responsibilities.

On the initiative of the head and/or senior directors of HCFs should be designated a waste management officer (WMO). He or she has the overall responsibility for the development of the HCWM plan and supervises the operation of the HCWM system [33]. In some countries the appointment of a WMO is legally prescribed.

Note: The Head of Hospital retains overall responsibility for ensuring that all wastes are disposed of in accordance with national (and international) guidelines. [33]

The head of the HCF should form a waste management team (WMT) to support the development of a waste management plan after the designation of the WMO. Later the WMT is among other things responsible for the periodic review of the HCWM plan. In addition to the WMO, the following persons should be integrated and/or new be designated into the team:

- Head of Hospital (as chairperson),
- Head's of Hospital Departments,
- Infection Control Officer,
- Chief Pharmacist,
- Radiation Officer,
- Matron (or Senior Nursing Officer),
- Hospital Manager,
- Hospital Engineer,
- Financial Controller. [33]

Note: In some HCFs the health-care waste management is the responsibility of an infection control committee (ICC) including the infection control officer (ICO). Then the infection control officer should draft the plan. [36]

The individual responsibilities and duties within the HCWM in large facilities are listed in the following paragraphs. A typical HCWM structure with line management responsibilities and liaison paths is shown in Abb. 4. This exemplary structure may be adjusted to the particular circumstances of each HCFs.

Head of Hospital

- nomination of members of the waste management team to develop waste management plan;
- designation of a Waste Management Officer (WMO);
- keeping of the management plan up to date;
- allocating of sufficient financial and personnel resources to ensure efficient operation of the plan;
- ensure the incorporation of monitoring procedures in the plan;
- ensure the adequate training for key staff members [33]

Department Heads

- responsibility for segregation, storage, and disposal of waste generated in their departments;
- ensure that all doctors, nurses, and clinical and non-clinical professional staff in their departments are aware of the segregation and storage procedures;
- continuously cooperation with the WMO to monitor working practices for failures or mistakes;
- ensure that key staff members in their departments are given training in waste segregation and disposal procedures [33]

Matron and Hospital Manager

- responsibility for training nursing staff, medical assistants, hospital attendants and ancillary staff concerning the HCWM;
- close cooperation with the WMO and the advisers to maintain the highest standards;
- participation in staff introduction and training, and cooperation with Department Heads to ensure the correct handling and disposal of health-care waste [33]

Waste Management Officer (WMO)

- responsibility for the day-to-day operation and monitoring of the waste management system;
- close cooperation with Infection Control Officer, the Chief Pharmacist, and the Radiation Officer in order to become familiar with the correct procedures;
- monitoring of the internal collection and transport of waste containers;
- close cooperation with the Supplies Department to ensure a optimal supply of bags, containers, protective clothing, and collection trolleys;
- ensure the replacing used bags and containers with the correct new bags or containers;
- supervision of hospital attendants and ancillary workers assigned to collect and transport health-care waste;
- ensure the correct use of the central storage facility for HCW by authorized staff;
- coordination and monitoring of all waste disposal operations;
- monitoring of methods of transportation of wastes (on- and off-site) and ensuring of the transport by an appropriate vehicle;
- ensure the maximum storage time of certain waste types;
- cooperation with the Matron (or Senior Nursing Officer) and the Hospital Manager to ensure a conformed to requirements and safe segregation and storage of waste;
- cooperation with Department Heads to ensure that all doctors and other qualified clinical staff are aware of their own responsibilities regarding segregation and storage of waste;
- ensure the availability of written emergency procedures and awareness of the action by staff;
- investigation and review of any reported incidents concerning the HCWM;
- participation in development of environmental friendly, waste-poor products and procedures [33]

Infection Control Officer

Note: In certain HCFs exists within the structure a Hospital Hygienist, to address specific problems relating to hospital hygiene. This person works closely with the infection control officer or meets his all functions. [33]

- cooperation with the WMO on a continuous basis and providing of advice concerning the infection control and the standards of the waste management;
- identifying of training requirements according to staff grade and occupation;
- organisation and supervision of staff training courses on safe waste management;
- cooperation with the Department Heads, the Matron, and the Hospital Manager to coordinate the training;
- overall responsibility for chemical disinfection, sound management of chemical stores, and chemical waste minimization [33]

Hospital Engineer

- responsibility for installing and maintaining waste storage facilities and handling equipment
- responsibility for the adequate operation and maintenance of any on-site waste treatment equipment and for the staff involved in waste treatment,
- ensure that staff receive training in the principles of waste disposal and are aware of their responsibilities under the hospital waste management plan;
- ensure that staff operating on-site waste treatment facilities are trained in their operation and maintenance [33]

Chief Pharmacist and Radiation Officer

- responsibility for the sound management of pharmaceutical (radioactive waste) stores and for pharmaceutical (radioactive) waste minimization;
- cooperation with Department Heads, the WMO, the Matron, and the Hospital Manager, giving advice, in accordance with the national policy and guidelines, on the appropriate procedures for pharmaceutical (radioactive) waste disposal;
- coordination of the continuous monitoring of procedures for the disposal of pharmaceutical (radioactive) waste;
- ensure that personnel involved in pharmaceutical (radioactive) waste handling and disposal receive adequate training;
- ensure the safe utilization of genotoxic products and the safe management of genotoxic waste (only the chief pharmacist) [33]

Supply Officer

- cooperation with the WMO to ensure a continuous supply of the items required for waste management
- investigation of the possibility of purchasing environmentally friendly products (e.g. reusable products) [33]

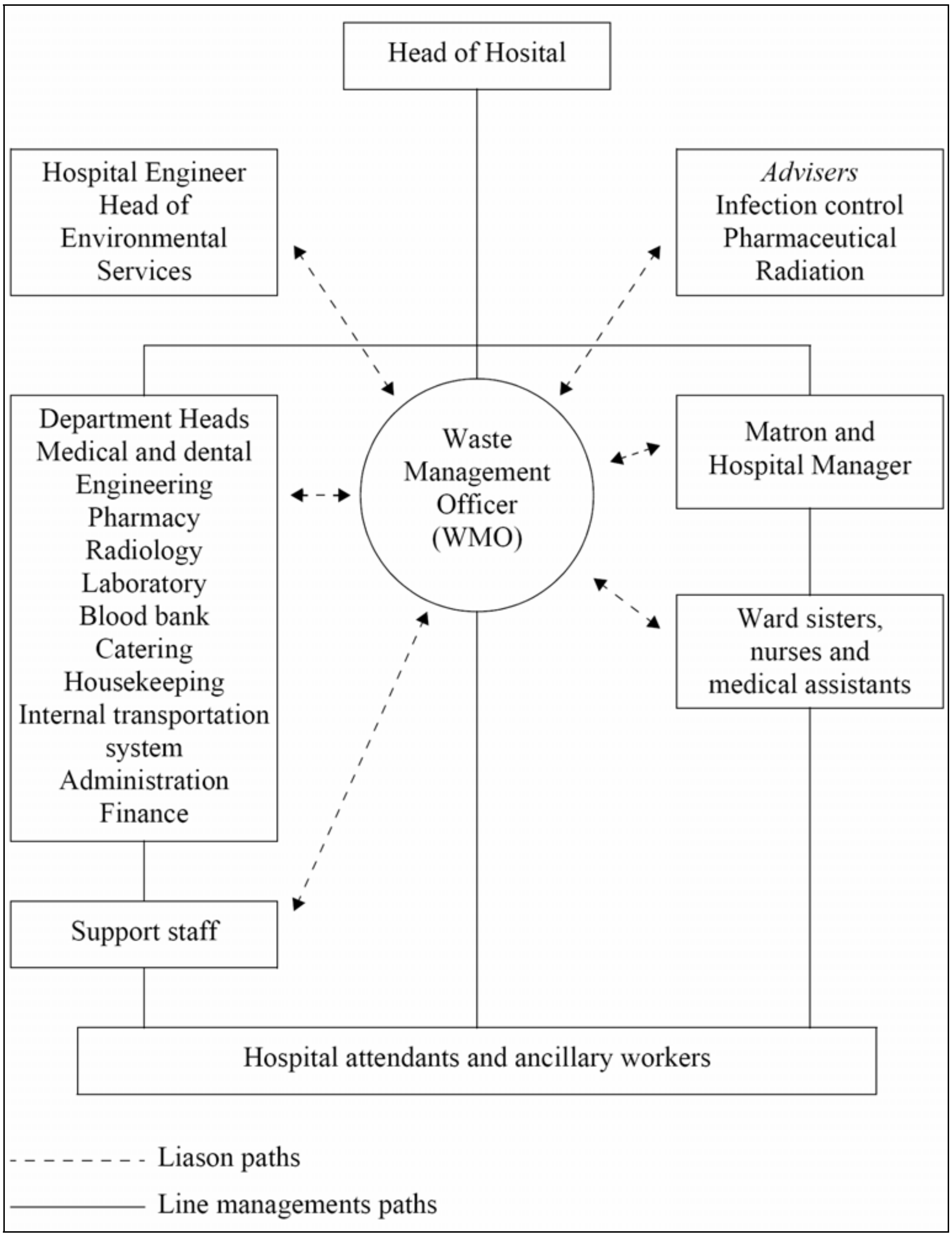

Abb. 4 Exemplary HCWM structure

Step 2: Accomplishment of a HCWM survey and invitation to suggestions

The current situation relating to the HCWM within HCFs should be registered and summarized in a survey to identify necessary improvements. The coordination and the analysis of the survey should be made by the WMO. In this regard it is helpfully to cooperate closely with head nurses. [36]

In the run-up general characteristic information are to be compiled, such as types of waste generated, number of beds, occupancy rates, types and number of wards/units departments. [36]

In the survey more specific data are to be registered, i.e. waste composition, waste quantities, sources of generation and number of beds in use. [36]

The collection and interpretation of the basic data is easier by the use of specific software, particularly used in industrial nations. With this it is also possible to compile cost centres and to control continuous the development of waste generating rates.

Results should be presented in the form of average daily quantity (kg) of waste generation in each waste category from each ward or unit. Unusual circumstances which may cause significant cyclical variations in waste quantities are to be considered as necessary. Epidemics and other emergencies may affect the quantities of waste generated and should also take to account. The waste generation survey is the basis for identifying opportunities for improving waste collection, handling and disposal.

Furthermore a series of other acts should be accomplished, particularly:

- preparation of an inventory of existing HCW treatment and disposal facilities and an evaluation of their efficiencies and capacities and of the prospective costs;
- conduction of a critical review of existing waste management practices;
- quantifying the number of the equipment used in waste handling, i.e. of collection containers;
- identifying of the costs related to waste management (incl. internal and external logistic expenses);
- description of the responsibilities and roles of staff involved in hygiene control and waste management considering their skills;
- assessment of the existing practice/opportunities for waste minimization, reuse and recycling;
- assessment of an existing colour coding system for waste collection;
- assessment of existing safety and security measures;
- evaluation of the emergency response capacity (considering large quantities of HCW in case of epidemic outbreaks of diseases);
- evaluation of the contingency measures applied in case of a breakdown of HCW treatment plants or during close down for planned maintenance;
- assessment and/or development of a training and awareness-raising programme [36].

An exemplary questionnaire to collect data about HCWM within an HCFs shows Abb. 5.

Questionnaire

Inspection or filled by the personnel

General:

name, location ward / unit: ____________________

disposal room ☐ location / room number: ____________________

Waste at hand:

- **General waste:** ☐
  characterisation of handling: ____________________
  type of used containers: __________ No. of containers: __________
- **Sharps:** ☐
  characterisation of handling: ____________________
  type of used containers: __________ No. of containers: __________
- **Infectious waste:** ☐ principal constituents: __________
  characterisation of handling: ____________________
  type of used containers: __________ No. of containers: __________
- **Pharmaceutical waste:** ☐ principal constituents: __________
  characterisation of handling: ____________________
  type of used containers: __________ No. of containers: __________
- **Chemical waste:** ☐ principal constituents: __________
  characterisation of handling: ____________________
  type of used containers: __________ No. of containers: __________
- **Cytotoxic waste:** ☐ principal constituents: __________
  characterisation of handling: ____________________
  type of used containers: __________ No. of containers: __________
- **Waste with high contents of heavy metal:** ☐
  principal constituents: __________
  characterisation of handling: ____________________
  type of used containers: __________ No. of containers: __________

Abb. 5 Exemplary questionnaire to collect data about HCWM within a HCFs

Apart from the pure data acquisition and –evaluation it is helpful to use (engineering) drawings. If these are not available, it is advisable to made meaningful sketches.

Sketches and/or drawings of HCFs should include the following components:

- the layouts of important units and wards;
- central waste storage areas (incl. refrigeration facilities);
- location of on-site treatment and disposal facilities (if any);
- waste collection trolleys routes through the HCFs;
- areas for washing and disinfecting waste collection trolleys;
- security equipment [36].

Drawings and/or sketches of each medical department, floor or building should include:

- location of individual HCW collection points (unclean rooms);
- location of temporary storage areas/containers;
- internal transport routes of waste in medical units/wards (at least for hazardous waste);
- location of patient rooms (e.g. intensive care unit) [36].

Step 3: Recommendation of HCWM improvements and preparation of a set of arrangements for their implementation

Preparation of recommendations

After the designation of responsibilities and the accomplishment of a HCWM survey, the WMO or ICO should prepare recommendations to improve or setting up the HCWM within the facility. Substantial components should be:

- staff responsibilities and roles,
- training needs,
- staff and equipment resources. [36]

HCFs that improve their existing HCWM system should identify available management options with the focus of sustainability. At the choice of management and disposal options the following criteria should be considered:

- worker safety,
- environmental-friendliness,
- affordability,
- efficiency,
- prevention of the re-use of disposable medical equipment (e.g. syringes),
- social acceptability. [36], [37]

HCFs that setting up a comprehensive HCWM system should start with basic measures:

- assignment of waste management responsibilities to personnel,
- allocation of sufficient human and financial resources,
- waste minimization,
- segregation of waste into hazardous and general HCW categories,
- implementation of safe handling, storage, transportation, treatment and disposal options. [36], [37]

The above-mentioned criteria in improvement are also to meet when setting up the HCWM.

Differentiated measures with respect to waste segregation, internal storage and collection to improve and/or setting up the HCWM are specified in section 6 "Safe handling, storage and transportation".

Costs associated with HCWM

Generally internal possibilities exist to realise financial savings by an improved HCWM. But it is necessary, to know the exact composition of the total costs of HCWM. The individual costs are predominantly:

- treatment and disposal costs (e.g. costs of landfilling and transportation),
- revenues which can be obtained (e.g. sale of potential recyclables),
- costs of internal logistics (capital-, operation- and maintaining costs),
- costs of rented or acquired containers,
- taxes and fees if necessary.

The possibilities of the internal influencing control are frequently simple to convert. For example: An important way to minimize disposal costs is the increasing of the collection rate of recyclable waste by additional recycling bins. Costs can also be minimized through cooperation between HCFs, e.g. by the establishment of a central treatment plant [36]. In consideration of the given maximum storage time and minimised transport costs the choice of an optimal fetching rotation can likewise lead to cost reductions.

Implementation of the proposed HCWM improvements

The prepared measures for the improvement of the HCWM should be components of the HCWM plan. The safe implementation of HCWM improvements should be developed and controlled by the WMO and/or the ICO. It is helpful to use a work plan or protocol including practical approaches/steps and to be in close cooperation with the head nurses of medical departments and in consultation with the WMT members. [36]

It is useful to implement the prepared measures first in one or more departments of the HCFs. Thus arising problems can possibly be limited to a subrange. Additionally thereby the possibility for the practical training of the staff is given.

A work plan for implementation of HCWM improvements may include the following elements:

- methods and timetable for implementing,
- checklists to assist nurses during the implementation process,
- training and awareness-raising activities to introduce procedures for implementation of planned activities,
- detailed information on safety practices and emergency response in case of incidents or accidents associated with HCWM,
- health surveillance and control and provision of information on rapid access to post-exposure prophylaxis,
- performance of standards and indicators to assess the effectiveness of HCWM improvements,
- contingency measures, including instructions on storage or evacuation of HCW in case of breakdown of treatment plants or during close down for planned maintenance [36].

Step 4: Draft of the HCWM plan

The HCWM should be drafted by the WMO and/or ICO in consultation with each member of the WMT based on the results of the situation assessment phase and its recommendations [36].

Irrespective of the scale of the HCWM plan, the following three aspects should be included:

- overview and examination of the current HCWM situation (Step 2),
- analysis of substantial resources for improving HCWM and derivation of possible options for improvements (Step 3),
- preparation of a detailed set of arrangements to implement the proposed waste management improvements (Step 3) [36].

Management within HCFs should be regarded as a holistic system. The individual components (purchase, distribution and waste management) interact. Hence other health-care management plans (e.g. safety management plan, security management plan, emergency preparedness plan, and equipment investment plan) should be considered and implemented if necessary [36].

Step 5: Approval of the HCWM plan and starting implementation

The draft of the HCWM plan should be approved by the HCF management after discussion within the WMT. The head and/or the WMO/ICO of the HCF should implement the HCWM plan shortly after. [36]

Step 6: Review of the HCWM plan

The efficiency and the sustainability in the long run are only to ensure by a periodic review of the HCWM plan (e.g. every two years). The liability of the review should have the WMT and/or the infection control committee. [36]

At frequent intervals (e.g. monthly) the WMT/ICC should monitor the implementation of the HCWM plan determine necessary subsequent adjustments.

Local authority representatives should be invited to the meetings or should be considered as permanent members of the WMT. Thus both a close co-operation with the authorities and a discussion platform are realized. Points need to clarified during the meetings are mostly the safe off-site transport and the final disposal of hazardous and highly hazardous HCW. [36]

1.4.5 Management of health-care waste from scattered small sources

Scattered small HCFs in some middle and lower-income developing countries do not have the necessary financial and personnel resources to designate a waste management officer or the members of an infection control or a waste management committee. Nevertheless these HCFs can improve or setting up the HCWM by simple measures. The top priority should be given then to the improvement of the hygiene practices. The gravest activities in this regard are the HCW segregation, internal collection and storage. In particular it is necessary to differentiate the wastes separately according to their hazard potential and to collect and to disposal these according to the regulations. Once at the source segregated waste may not be mixed afterwards. [35]

Since a pronounced HCWM structure is missing, the manager has to approach directly the departments and cooperate with its senior nurses and doctors to ensure sound practices in his HCF. Thus the number of persons who are to organize is reduced and it takes place a concentration on certain problem areas [35]. Additionally small HCFs should draw an infection control policy containing details of the procedures to follow in case of exposure to infected blood or a needle-stick injury. These should be easily understandable and always available [33].

In the following precautions regarding a proper HCWM for different types of smaller HCFs are described.

Private medical or dental practitioners

- application of specific containers for HCRW (sharps and infectious waste),
- information on policy and procedures of HCWM,
- involvement in training [33]

Research activities

- handling of highly infectious waste only by well trained and authorized staff,
- on-site disinfection or incineration of highly infectious waste (including small animal carcases) or,
- if on-site treatment is impossible or uneconomical: cooled storage of highly infectious waste until the pickup by a waste contractor or carrier [33].

Nursing homes

- training of all personnel and implementation of proper segregation practices,
- application of specific containers for HCRW (sharps and infectious waste) [33]

Home treatment

- packaging of sharps in small puncture-proof containers and following disposal with the general domestic waste (diabetics should return them to the physician),
- double-packaging of other HCW in plastic bags and following disposal with the general domestic waste,
- safely packaging and transfer to the treating physician of HCW produced by chemotherapy treatments (needles from infusion sets or syringes, and protective gloves, contaminated with cytotoxic drugs) [33]

Ambulance services

- preparation of policies for the safe handling of HCW,
- application of specific containers for HCRW (sharps and infectious waste),
- training of ambulance staff regarding HCWM [33]

1.5 Measures of environmental protection and cost reduction

It became already apparent that due to a proper waste management environmental protection interests are considered and at the same time cost savings are obtained. Significant methods are waste avoidance and the recycling or safe reuse of used materials.

1.5.1 Measures concerning waste management

Environmental protection interests can be achieved by simple but effective measures. On the downside, changes go a long way.

The emphasis places on the container-management. In the following are some examples listed to conform and to improve the waste-management in larger HCFs:

- analysis of disposal costs by weight and volume to determine a baseline,
- control of the contents of collection containers,
- warranty of the easily accessibility of containers for staff,
- account of removal waste by department,
- verification of pick-up schedules,
- verification of the internal disposal routes and schedules,
- optimisation of containers size (availability versus need),
- purchase of containers made out of the highest percentage possible of recycled materials,
- use of non-toxic bag dyes and lettering,
- appropriation of one larger container centrally located to replace numerous patient-room containers,
- involvement of staff in container placement,
- involvement of contracted housekeeping companies in the waste minimisation practices,
- survey of the eventuality to treat suction canisters (to dispose them with the general solid),
- if necessary: translation of labels,
- matching of containers by colour for each waste category,
- statement of the arising disposal costs for all employees,
- requirement for “less packaging” and “take back” policies, if appropriate,
- close cooperation with suppliers to realize waste minimization programmes.

1.5.2 Waste avoidance and minimisation

The avoidance of waste should take priority over the recycling of used materials. In Europe is this priority regulated by law. Cost savings can be realised owing to the avoidance of waste, e.g. via a reduction of provided collection bins.

The avoid-potential (particularly of specific HCW) is limited in HCFs because the security of supply is to be ensured. However, it exist intern measures to reduce the quantity of waste and the cost involved:

- an ecological-oriented purchase (methods and supplies that are less wasteful),
- the application of reusable- instead of disposable,
- careful waste segregation into the different categories to minimize the quantities of hazardous waste,
- the avoidance of unnecessary articles and packages.

It is meaningful to find out and to implement minimisation-measures of waste with a comparatively high cost-relevance first. Thus drastic cost savings can be realised as a result of poor reduction of waste quantities.

The data concerning the waste generated and the disposal costs alone are not sufficient for the determination of the cost relevance. Rather it is necessary to compare the specific percentage of waste quantity with the resulting costs.

Abb. 6 compare the quantities of waste and the disposal costs of a hospital of the maximum supply in Germany. Thus it appears that general waste amounts 50 percent of the total quantity but causes only circa one third of the costs. In contrast: waste requiring special supervision (hazardous), such as infectious waste, have an inversely cost-quantity-ratio. Hence, a minor decrease of waste generated has already a significant effect on the disposal costs incurred.

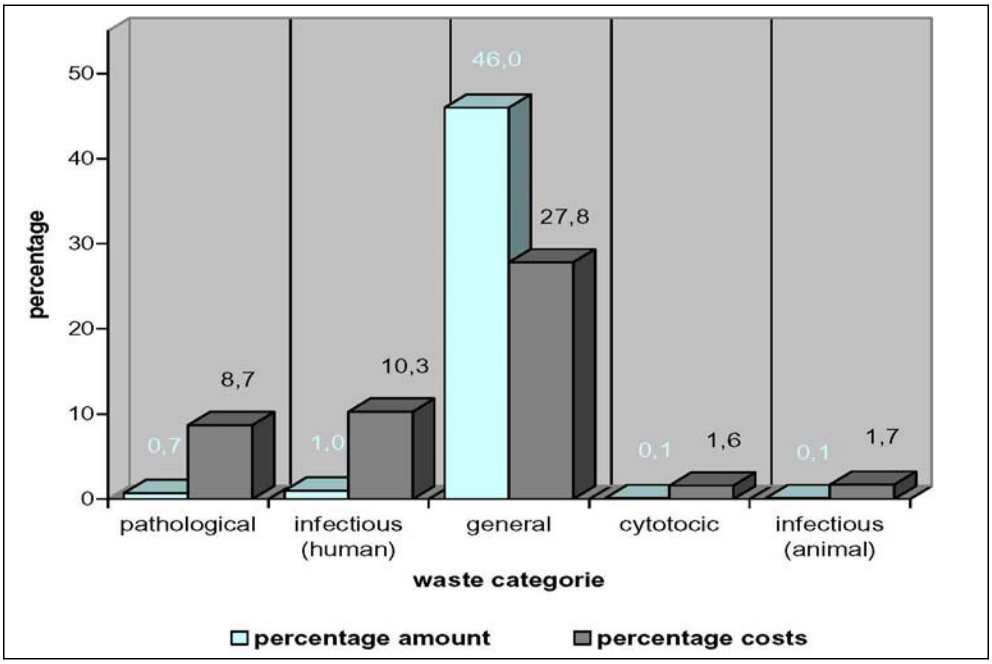

Abb. 6 Comparison of percentages of amount and costs

A minimisation of the infectious wastes generated is gettable primarily by the prevention of misallocation. Quantity reductions are additional possible by the employment of products with comparatively small material expenditure.

Different investigations ([38], [39]) showed that many employees need an exact listing of the infection diseases, which go along with the generation of infectious waste at the treatment of patients and which are relevant for the HCFs. An effective possibility to make the necessary information available is the attachment of specific teaching-poster (if possible in the proximity of points of disposal). In this regard is the cooperation of the waste management officer with the infection control officer (and/or the hospital hygienist) and the managerial nursing staffs essential (closer explanations concerning this topic are specified in section "training").

Beside the internal waste avoidance and minimisation cost reductions can be realized by the choice of a disposal route. The internal treatment of infectious wastes reduces the quantity which is to dispose of and can reduce thereby the costs under certain conditions.

The avoid-potential of pathological waste is slight. However the false allocation of these waste category causing extra costs should be avoided also by information and training course measures of the personnel.

A similar slight avoid-potential has the category of cytotoxic waste. Particularly large HCFs should exactly specify which materials and which (liquid) residues are belonging to this waste category. Experiences show that a central preparation and packaging (e.g. in a central pharmacy) of cytostatic drugs and the subsequent transmission to the places of application can avoid cytotoxic waste as well as waste bins.

Waste with high contents heavy metals can be avoided best by an adapted purchase. The heavy metal mercury can be avoided especially by replacement. Nickel-cadmium batteries can be avoided by the application of non-mercury (rechargeable) batteries. Mercury-thermometers should be replaced with electronic battery-operated thermometers.

Apart from the special measures specified fundamental measures exist to minimise the quantity of waste. Examples for waste avoidance and waste minimisation structured into different areas are listed in the following (Source: [39]):

Out-patient department

- collection of paper at special designated points to avoid contamination with other waste,
- covering examination benches only in the area where skin makes contact with base
- reconditioning developers for X-ray films

Technical Department

- separate waste oil collection for incineration in cement furnaces
- reconditioning solvents
- separate collection of batteries

House cleaning and disinfection/sterilisation

- separate collection of cartons from packaging
- use of large multiuse packing units

Nursing wards

- reusable textile napkins,
- reusable medicine bowls (made of glass),
- central collection of unused drugs in the pharmacy and return to suppliers,
- metal kidney bowls for multiple use,
- collection of paper at special designated points to avoid contamination with other waste,
- use of secretion and urine bags with discharge devices, change as required

Operating theatre

- no disposable overshoes,
- reusable frocks and aprons,
- separate collection of solvents and cartons from packaging,
- reusable for personnel,
- use of reusable instruments

Laboratory

- separate collection of paper,
- central management and storage of toxic substances,
- separate collection of solvents and alkaline in special canisters with letter markings for regeneration,
- concentrating toxic substances from solvents, e.g. ethidium bromide on adsorption columns,

Storage

- use of reusable standard pallets,
- separate collection of plastic film outer wraps,
- data evaluation on material flow to hospital,
- separate collection of cartons,
- large packaging refilled in smaller units as required

Pharmacy

- reuse of empty containers,
- infusions in glass bottles instead of plastic bags,
- separate collection of cartons,,
- collecting unused drugs and medicines, return to supplier,
- in-house production of ultrasound gel,
- in-house production of liquid nourishment in reusable bottles (only if not infused!),
- reusable gallows for infusion bottles

Laundry and laundry shop

- bags for dirty washing made of drapery,
- reuse of residues from dry-cleaning

Kitchen and canteen

- collection of cartons and compressed in baling press,
- separate collection of plastic film outer wraps,
- no disposable cutlery and dishes,
- reusable bottles and drinking fountain for carbonated tap water

Administration

- separate collection of paper, avoiding crumbled paper for denser packing
- refillable cartridges for printers and copiers (and/or sale of used cartridges)

Purchase

- use of recycled paper instead of white paper,
- integrating waste charges in negotiations with supplier,
- purchasing refillable cartridges for printers and copiers,
- purchasing high quality cartridges with higher page rates for copiers and printers

Waste minimisation usually influences the waste management positively. The costs for purchase of supply goods and for waste treatment and disposal are reduced and the liabilities associated with the disposal of hazardous waste are lessened. [33]

Note: The usage of reusable products must be analysed, especially in developing countries. Several developing countries don’t dispose of sufficient drinking water deposit. In this cases, the application of disposable is more appropriate, also under environmental considerations.

1.5.3 Safe reuse and recycling

1.5.3.1 Collection of potential recyclables

The percentage of recyclables included in HCW is high (see above table 18). In addition the collection of potential recyclables in HCFs is often to be accomplished on the basis of legally determines similarly waste avoidance. The collection of recyclables is consequently a vital element of HCWM.

An increased collection of potential recyclables in hospitals is a direct measure of environmental protection and involves additionally cost savings. The collected materials can be delivered as far as possible free of charge or even proceeds generating. In addition a decrease of quantities of general waste is leading to cost savings by lower charges for disposal.

The basis for proper collection of recyclables is the strict and legal segregation of the specific waste categories. This is the best way to avoid the contamination of recyclable materials.

In hospitals the following fractions of the general waste stream can be collected separately and recycled subsequently:

- glass,
- paper (such as newspaper), paper and carton packages,
- tinplates,
- aluminium and
- bio-waste.

The recyclable collection system must meet the specific requirements existing in HCFs. The collection-containers used should be space saving, easy to clean (if these are reused) manageable. Returnable collection-containers in sanitarily sensitive areas, such as these in operation theatres, must be easy to disinfect before a new use. The collection realised in areas of patient care should avoid annoyance due to noise as possible (dropping of glass). The container should be well-identified by a colour coding system. The basis should be the colour coding system used by collection in private households to increase the acceptability by employees, patients and visitors.

However, the collection effort should be in balance with the attainable ecological and economical benefits. The investment costs for the collection-containers, the additional expenditure of time to separate and collect the recyclables and the effort to inform patients, visitors and employees shouldn’t be out of scale. It can be necessary to modify or to newly arrange already existing contracts, if external service enterprises are included in HCWM.

In some countries already specific cancelling systems for potential recyclables exist. In Germany reusable medicine bowls made of glass resulting in larger quantities are collected separately and returned afterwards directly to the manufacturers of the pharmaceutical industry.

1.5.3.2 Safe reuse of medical equipment

The reuse of medical and other equipment used in a health-care establishment requires that the products are designed multiply use and withstand the sterilization process.

The possibilities of the application of reusable items are manifold. But disposable products are mostly cheaper and easier to handle. Several scientific studies, however, proved the usefulness of reusable products under the aspects of work practice, economy and ecology.

A common application in developing countries is the reuse of certain sharps, such as hypodermic needles, syringes, and scalpels. These are separately collected, carefully washed and then sterilized. However, this practice should be ceased. It may cause risks for personnel and patients.

Larger facilities possess their own central sterilisation plant to treat surgical instruments and textiles. Methods to sterilise medical items are listed in following table.

Tab 32 Methods to sterilise reusable items

Method	Sub-type or active agent	Explanation
Thermal sterilisation	Dry sterilisation	Exposure to 160°C for 120 minutes or 170°C for 60 minutes
	Wet sterilisation	Exposure to saturated steam at 121°C for 30 minutes
Chemical sterilisation	Ethylene oxide	Exposure to an atmosphere saturated with ethylene oxide for 3-8 hours in a reactor at 50-60°C Ethylene oxide is very hazardous! Highly trained and protected personnel is essential
Source: [33]		

The sterilisation of hypodermic needles is not recommended. However, in certain circumstances is this procedure indispensable, e.g. if means are poor. Catheters and syringes made of plastic should be discarded. [33]

Material, which is principally used invasive, such as scalpels, must be generally sterilised. That applies to textile materials used in aseptic areas too.

In the case of potential or proven contamination with the causative agents of transmissible spongiform encephalopathy (TSE, e.g. CJD) are the above-mentioned methods insufficient. The WHO demands more extensive measures, such as the wet sterilisation at 134 to 138°C for 18 minutes for porous-load autoclaving and 132°C for 60 minutes for gravity-displacement autoclaving. [40]

The effectiveness of sterilisation must be periodically checked with the aid of bio-indicators to ensure the disinfectant effect. The most common organisms are Bacillus stearothermophilus for thermal sterilisation and Bacillus subtilis for chemical sterilisation.

Like above-mentioned it is possible to reuse (transport-)containers. Measures to ensure hygienic requirements are described in the next section.

1.6 Safe handling, storage and transportation

Due to the different characteristics of the waste categories generated in HCFs result different requirements on collection, packaging, transport (off-site and also on-site) and storage. Appropriate HCWM practices protect health and environment and reduce costs.

1.6.1 General explanations

The identification and strict segregation of waste by category as close as possible to the place of generating are important preconditions to minimise waste and to ensure an effective HCWM associated with hygienic aspects.

The waste segregation should occur as early as possible, for example, when an injection is given, or when packaging is removed from supplies. HCW must always be segregated into hazardous HCW and general waste. It is the aim to minimise the amount of hazardous waste requiring special treatment and disposal techniques. The mixing of different waste streams inflates the amount of waste that requires special treatment hence increasing the cost of treatment and disposal. If infectious and other hazardous wastes are blended together, the mixture must be treated as *both* hazardous and infectious. Some waste haulers permitted to haul hazardous waste will not accept mixed hazardous and infectious waste; the entire mixture will have to be rendered non-infectious first and then hauled as hazardous waste. If general waste is added to infectious waste containers, the combined quantity must be treated as infectious waste. [41]

No healthcare waste other than sharps should be collected in sharps containers, as these containers are more expensive than the containers or bags used for other infectious waste. To improve segregation efficiency and minimise incorrect use of containers, the proper placement and labelling of containers must be carefully determined. General waste containers placed beside infectious waste containers could result in better segregation. Too many infectious waste containers tend to inflate waste volume but too few containers may lead to non-compliance. Minimising or eliminating the number of infectious waste containers in patient care areas (except for sharps containers which should be readily accessible) may further reduce waste. The HCFs should develop a segregation plan that includes staff training and direct education and information materials. Measures of this sort are the basis to minimise the costs of HCW collection and treatment.

By segregating waste, appropriate resource recovery and recycling techniques can be applied to each separate waste stream. Moreover, the amount of infectious, the quantities of other hazardous wastes to be treated and the low-level radioactive waste are minimised. Another crucial reason for segregation has to do with the negative consequences of introducing hazardous or radioactive substances into treatment systems for infectious waste. [41]

All used collection and transport bins that will be incinerated should be made of PVC- and cadmium-free materials to consider environmental aspects.

Hazardous waste generated should be collected in regulation packaging on the place of generation and should remain there short-time as possible because of the latently existing spreading danger of diseases. The subsequent sorting and mixture must be eliminated because of the resulting risk of injury or infection.

A routine programme of waste collection should be inherent part of the health-care waste management plan. Usually the waste should be removed depending upon accumulation quantity and hazard potential at least once, better several times per day. The waste bins should be replaced with new ones at the removal. The waste bins should be labelled with the HCF name and the notation of ward or department to trace the point of generation. Where a waste bag is removed from a container, the container is properly cleaned before a new bag is fitted therein. Protective gloves, goggles and overalls should be provided to transporting personnel to reduce the risk of infection and injury from waste.

An effective but plain way to identify the different categories of HCW is the use of colour coded bins. The collection-bins have to meet special requirements subject to the respective waste characteristics. Some categories of waste may be disposed via different disposal routes (incineration or disinfection of infectious waste). The disposal route chosen interferes additionally the properties of collection bins (see section 1.7 “Treatment and disposal of infectious waste”).

The usage of trolleys is less risky than manual carrying in bags. If a used syringe needle or blade has been mistakenly placed in a bag and protrudes out it could injure and infect transporting personnel when carried without care. The waste collection trolleys used for on-site transportation shall be free of sharp edges, easy to load and unload and to clean, and preferably a stable three or four-wheeled design with high sides. The waste trolley shall not be used for any other purpose. They should be kept shut during transport to prevent spillage and avoid offensive sights and odours and should be cleaned regularly, and especially before any maintenance work is performed on it. The trolleys should be cleaned and disinfected daily with an appropriate disinfectant.

The on-site collection route shall be the most direct one from the final collection point to the central storage facility designated in the Waste Management Plan. The collected waste shall not be left even temporarily anywhere other than at the designated central storage area. There should be two separate central storage areas at each HCF:

- for hazardous HCW; and
- for general HCW [4].

Typically, bins containing infectious and used sharps are stored in the same central storage area due to the treatment and disposal route chosen is usually the same for both [4].

The design and location of central storage should ensure following aspects:

- prevention of access for unauthorised persons,
- prevention of attraction for vermin and other animals,
- protection against wind and rain,
- cool storage in hot climates,
- separate storage for different waste categories,
- storage locations used for hazardous waste should be lockable.

Types of storage rooms (at or near the ward and central storage room) should be well ventilated and kept clean to prevent infections of the personnel. The separate central storage facility used for hazardous waste should be labelled with a sign prominently displaying the biohazard symbol and it should be obvious that the facility stores hazardous waste.

The central storage facility should be located within the hospital premises close to the treatment unit, if installed, but away from food storage or kitchen. The room should be large enough to contain all the hazardous HCW waste produced by the HCFs, with spare capacity to cater for collection or treatment unit breakdowns. Cleaning and disinfection should be easy to realise. Adequate cleaning equipment, protective clothing and waste bags and containers should be located nearby.

Hazardous health-care waste should be transported on public roads by the quickest possible route. After departure from the waste production point, every effort should be made to avoid further handling. HCFs are responsible for safe packaging and adequate labelling of waste to be transported off-site and for authorisation of its destination. The national and international regulations governing the transport of hazardous wastes must be considered. The most important regulation regarding hazardous waste transport is “Recommendations on the transport of dangerous goods” in the 14th edition, published by the United Nations. These requirements were developed in coordination with experts from the World Health Organization (WHO) and other technical experts in the field of transport, packaging and health.

In Europe applies the “European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)”. This regulation was done at Geneva on 30 September 1957 under the auspices of the United Nations Economic Commission for Europe, and it entered into force on 29 January 1968.

Highly infectious waste should not be transported off-site as possible. This kind of waste should be treated inside of HCF as near by the point of production as possible.

The special practices subject to different waste categories which can be generated in HCFs are mentioned in the following.

1.6.2 General waste

General waste should be collected separately to bring down disposal and treatment costs. This type of waste can be incinerated (in a municipal incinerator) or landfilled (in a sanitary landfill) without pre-treatment.

General waste containing waste contaminated with facultative pathogens (for example dressings, plaster casts, linen, disposable clothing and diapers) must be handled with care within HCFs to prevent nosocomial infections and should be collected in tensile-proof and leak-proof plastic bins (such as sacks). Past experiences reveals that sacks made of recycled material are not suitable due to an insufficient tensile-strength [42].

The bins should be kept closed on the point of storage to prevent nosocomial infections. If plastic sacks are used, it is necessary to use self-locking tools. Abb. 7 shows exemplary a self-locking waste collector with wheels, a fixing brake and foot-operated closing device. The waste bags should be closed or sealed when they are about three-quarters full.

Abb. 7 Self locking waste collector

General waste including larger quantities of body fluids should not be collected in sacks but in dimensionally stable containers. Body fluids in waste should be absorbed by the use of purposive materials, if necessary. If these are not available, waste including larger quantities of body fluids must be assigned to pathological waste and must be handled like this.

Note: A smidgen of body fluids may be disposed of in the sewage water system provided that this is fully functional and an appropriate municipal treatment plant is available. Body fluids contaminated with radioactive substances must be interim-storaged in delay tanks before disposal in the sewage water system. The articles of the municipal sewage-disposal must receive attention!

Bins must be closed also on the course of transport to prevent nosocomial infections. Sacks can be closed via a wire (made of copper). Returnable transport-container should be disinfected and subsequently cleaned before a new use.

The decanting and the subsequent separation should be remained undone. General waste can be compressed in central compactor-containers which may be considered as part of the central storage and can act as mean of transportation (see following figure). In this case, the compactor-containers should include absorption substances (such as sodium polyacrylat, see following table) in adequate quantity to prevent the discharge of body fluids in the course of transit. Practical experiences show that most of the closed plastic sacks weather the compression without prejudice. The compression of compact (plastic) containers is inadvisable in this regard. The brittle plastic will be destroyed and the fluids if anything can discharge.

If wheelie bins are used to collect the general waste central, the lid of the wheelie bin should be kept closed. The lid must not be removed from the bin. The bins must not be overfilled so that the lid can be closed properly.

Abb. 8 Central waste storage hall with transportable compactors for general HCW

Tab 33 Characteristics of sodium polyacrylat

Flash point	Inapplicable
Ignition point	Undetermined
Body structure	White granulate
Odour	Odourless
Ecology	Neutral on landfills, combustion products: water vapour and carbon dioxide
Metering	Distilled water: 4 g / litre Sodium chloride solution (0,9%): 25 g / litre Water: 10 g / litre
Gel time	10 g / 1 litre water: ca. 5 min
Acute oral toxicity	> 2000 mg/kg rat LD 50
Cutaneous tolerance	Not skin irritating, washable with water and soap

Storage	Keep dry

1.6.3 Infectious waste

Infectious waste must be collected in humidity-resistant, tensile-proof and leak-proof waste bins on the place of generation. Containers and bags for infectious waste should be marked with the international infectious substance symbol pictured in Abb. 9 (for both internal and external transport).

Abb. 9 International infectious substance symbol

Sacks made of plastic or paper as sole packaging should not be used to transport the waste within HCFs. These should be enclosed with dimensionally stable containers as a second packaging.

Abb. 10 shows combustible plastics-containers to collect and transport infectious wastes used in Germany. The required leak-tightness is achieved by a special grommet on the container lid (see Abb. 11).

Abb. 10 Collection- and transport container for infectious waste

Abb. 11 Grommet on the lid of waste containers

Hazardous health-care waste and general waste may be stored in the same room, provided that the various categories are separated to the extent that it will avoid unintentional mixing

As most HCW contains biodegradable materials, the packaging should be tight and the storage time limited. The central storage room temperature should be kept down by protecting it from temperature increases resulting from direct sunlight and un-insulated corrugated iron walls/roofs. Although it is preferred that hazardous HCW be removed daily, the maximum storage time for HCW should be 72 hours (in moderate climates) and 48 hours (in hot climates) [43].

All HCW containing biodegradable materials (infectious and pathological waste), where required due to climatic conditions or extended storage periods, shall be cooled / refrigerated by means of dedicated cooling / refrigeration facilities for HCW at the central storage area.

The construction of transport container should meet demanding requirements, especially the “Recommendations on the transport of dangerous goods”. Transport containers for infectious waste should be design type-tested and certified as approved for use.

Infectious substances are well defined in the specific class 6.2 “Infectious Substances” of the Recommendations on the transport of dangerous goods. The substances of class 6.2 are classified as follows:

- Infectious substances, affecting humans (UN No. 2814)
- Infectious substances, affecting animals only (UN No. 2900)
- Clinical waste, unspecified, n.o.s, or (Bio)Medical waste, n.o.s., or Regulated medical waste, n.o.s. (UN No.3291)
- Diagnostic specimens

The designation "n.o.s." is the abbreviation of Not Otherwise Specified and should be used if the substance falls within a larger hazardous category but does not meet the criteria of any specific disorder within that category.

The infectious substances are classified in two different risk categories.

Category A: Infectious substances in a form that, when exposure to it occurs, is capable of causing permanent disability, life-threatening or fatal disease in otherwise healthy humans or animals.

Category B: Infectious Substances that do not meet the criteria for inclusion in category A.

The following table shows examples of infectious substances affecting humans included in category A in any form unless otherwise indicated. The micro-organisms written in italics are bacteria, mycoplasma, rickettsia or fungi.

Tab 34 Examples of infectious substances category A affecting humans

Bacillus anthracis (cultures only)
Brucella abortus (cultures only)
Brucella melitensis (cultures only)
Brucella suis (cultures only)
Burkholderia mallei – Pseudomonas mallei – Glanders (cultures only)
Burkholderia pseudomallei – Pseudomonas pseudomallei (cultures only)
Chlamydia psittaci – avian strains (cultures only)
Clostridium botulinum (cultures only)
Coccidioides immitis (cultures only)
Coxiella burnetii (cultures only)
Crimean-Congo hemorrhagic fever virus
Dengue virus (cult ures only)
Eastern equine encephalitis virus (cultures only)
Escherichia coli, verotoxigenic (cultures only)
Ebola virus
Flexal virus
Francisella tularensis (cultures only)
Guanarito virus
Hantaan virus
Hantavirus causing hemorrhagic fever with renal syndrome
Hendra virus
Hepatitis B virus (cultures only)
Herpes B virus (cultures only)
Human immunodeficiency virus (cultures only)
Highly pathogenic avian influenza virus (cultures only)
Japanese Encephalitis virus (cultures only)

Junin virus
Kyasanur Forest disease virus
Lassa virus
Machupo virus
Marburg virus
Monkeypox virus
Mycobacterium tuberculosis (cultures only)
Nipah virus
Omsk hemorrhagic fever virus
Poliovirus (cultures only)
Rabies virus (cultures only)
Rickettsia prowazekii (cultures only)
Rickettsia rickettsii (cultures only)
Rift Valley fever virus (cultures only)
Russian spring-summer encephalitis virus (cultures only)
Sabia virus
Shigella dysenteriae type 1 (cultures only)
Tick-borne encephalitis virus (cultures only)
Variola virus
Venezuelan equine encephalitis virus (cultures only)
West Nile virus (cultures only)
Yellow fever virus (cultures only)

HCW containing infectious substances of category A or infectious substances of category B as cultures must assigned to the UN No. 2814 or respective 2900. The packaging requirements for UN Numbers 2814 and 2900 are outlined in packing instruction 620. The packaging should comprise an inner and an outer packaging. The inner packaging comprising the following essential elements:

- watertight primary receptacle of plastics or metal with leak-proof seal;
- a watertight secondary packaging;
- absorbent material in sufficient quantity to absorb the entire contents placed between the primary receptacle and the secondary packaging.

The containers should be airtight, if air-transported highly infectious agents, such as Lassa virus and Marburg virus, are included.

The outer packaging must show an adequate strength for its capacity, mass, and intended use, and with a minimum external dimension of 10 cm, and should be appropriately labelled. The list of contents should be enclosed between the secondary packaging. [43]

The packaging and transportation requirements are high and can be ensured only by a few of carriers at present. Hence, HCW containing infectious substances of category A or infectious substances of category B as cultures should be managed as highly infectious waste and should be treated inside HCFs as near by the point of production as possible.

The requirements on packaging of waste with UN No. 3291 are not so high. This type of waste can be packaged in rigid and leak-proof packaging or in intermediate bulk containers - large rigid or flexible bulk containers made from a variety of materials.

The transport containers must be labelled with:

- the letters UN and the UN Number,
- the specific UN term,
- the UN dangerous goods symbol (see figure 11) and
- the word “waste” in the case of UN No. 2900 or 2814.

The required labelling depending on the risk categories are summarised in Tab 35.

Tab 35 Required labelling of transport containers for infectious waste

Risk category	Labelling
Category B excluding cultures	UN 3291 Clinical waste, unspecified, n.o.s,
Category A, affecting animals only	Waste UN 2900 Infectious substances, affecting animals only
Category B as cultures, affecting animals only	Waste UN 2900 Infectious substances, affecting animals only
Category A, affecting humans	Waste UN 2814 Infectious substances, affecting humans
Category B as cultures, affecting humans	Waste UN 2814 Infectious substances, affecting humans

The name of the waste generator, i.e. the HCF and department or unit at best, should be noted in addition to the required labelling.

Abb. 12 UN dangerous goods symbol class 6.2

1.6.4 Pathological waste

Recognisable human or animal body parts, tissues, organs, human foetuses, blood and body fluids should be collected in rigid and intransparent containers to take aesthetic aspects into account. To prevent the later opening, containers should be difficult to open.

The disposal route so chosen affects the necessary properties of containers. If pathological waste is incinerated, the containers must be consequently combustible. All specific containers with anatomical waste should be labelled "anatomical waste" (in addition with translation in national languages).

Experiences show that the collection and transport of larger body parts (i.e. amputated extremities) makes difficulties. The most of offered waste containers are unsuitable because these are too small and/or too heavy. On this reason, it can be necessary to purchase special containers for transport of larger body parts.

The data regarding maximal storage time specified in section 2.6.3 apply. In exceptional cases the available morgue can be used for short-time storage and cooling down of pathological waste.

1.6.5 Sharps

All sharp items should be collected together in break- and puncture-proof disposable containers fitted with covers. They should be additionally impermeable to prevent the discharge of possibly existing liquids from syringes. To obviate abuse, containers should be difficult to open and the sharp contents should be disabled. Containers offered by several manufactures are mostly made of high density plastic or metal to ensure the required mechanical properties. But the purchase costs can be high or containers are unavailable. In such cases it is meaningful to use rigid and labelled empty disinfectant-cans or containers made of dense cardboard supplied with a plastic lining (see Abb. 13) [43]. Glass bottles are unsuitable due to their fragility. It is recommended that closed sharps containers should be placed and transported in stackable and easy to transport boxes.

Collection and transport container including sharp items which are contaminated with obligate pathogens should be labelled such as described in Tab 35 above.

Abb. 13 Cardboard sharps container

Abb. 14 shows usual in trade plastic container used in Germany with a specific opening to separate easily metallic needles from the plastic syringe barrel. The volume of these collection- and transport containers amounts to one to five litres.

Abb. 14 Plastic collection- and transport container for sharps

Note: Vacuum Collection systems (Vacutainer) are widely used for the collection of blood. The needles unfortunately need to be recapped in order to be able to reuse the barrel. This is done using a ‘one hand technique’ whereby the needle ‘follows’ the cap. The needle should be unscrewed with care from the barrel and disposed of into the sharps container.

1.6.6 Chemical and pharmaceutical waste

The first objective should be for used or expired chemical and pharmaceutical waste to be recontainerised in the same containers by which it was initially supplied, for return to the suppliers of the products. The suppliers of these products are aware of their products and have mostly the knowledge to ensure the safe and environmentally sound treatment and disposal of chemical and pharmaceutical waste. However, this procedure is not existent in every country. One reason can be that used chemicals and pharmaceuticals are imported products.

Some liquid chemicals can for instance safely be discharged via the sewer. The amounts should be limited and the local regulations must be observed. Another alternative is to collect small quantities of chemical or pharmaceutical waste together with infectious waste, provided that the infectious waste is destined for incineration.

Larger quantities of chemicals and obsolete or expired pharmaceuticals that can not be recontainerised in the same containers by which it was initially supplied should be collected in special chemical resistant containers. They should be sent to special treatment facilities or returned to the supplier, if possible. Hazardous chemicals should be handled only by trained personnel. The mixture of unknown chemicals should be omitted. Resulting chemical compounds may be toxic and the reaction may proceed critical (i.e. appearance of high temperatures).

Spilled or contaminated drugs or packaging containing drug residues should not be returned because of the risk of contaminating the pharmacy. Special container should be used to collect this type of waste. [43]

Large quantities of chemical waste must be packed in chemical resistant containers and should be sent to special treatment facilities or returned to the supplier. Hazardous chemicals should be handled only by trained personnel.

1.6.7 Genotoxic / cytotoxic waste

The classification of cytostatic remaining quantities to this waste category is often a problem for the staff. On this reason, the facilities should define clear classification criteria (within the HCWM plan) and should inform the personnel about these.

Small quantities of cytotoxic waste may be collected together with infectious waste, provided that the infectious waste is destined for incineration.

Large quantities of cytotoxic waste are to be collected in special waste containers. These must be break- and puncture-proof disposable containers fitted with covers. Following figure sows two different containers used in Germany to collect, transport and dispose cytotoxic waste.

Abb. 15 Plastic collection- and transport container for cytotoxic waste

The subsequent sorting and mixture must be eliminated. The transport container used for external transport to the incineration plant must comply with national and international laws regarding the transport of dangerous goods.

Cytotoxic substances are included in the specific class 6.1 "Poisonous substances" of the "Recommendations on the transport of dangerous goods". The transport containers must be labelled with:

- the letters UN and the UN Number 2811,
- the specific UN term " TOXIC SOLID, ORGANIC, N.O.S."
- the UN dangerous goods symbol (see Abb. 16) and
- the word "waste".

Abb. 16 UN dangerous goods symbol class 6.1

The packaging requirements for UN Number 2811 is outlined in packing instruction P002.

1.6.8 Application of automated guided vehicle system

Automated guided vehicle systems (AGV) were applied for the first time in large industrial firms to realise logistic processes. In the meantime AGVs are also applied in developed nations to provide for product supply and internal transport and on-site waste transport in larger HCFs. The application of AGVs has the main advantage that the expensive personal requirement in developed nations is reduced. However, this advantage is only given by a concentration of departments at close quarters.

In addition to the economic efficiency, the application of an AGV has following advantages compared to the manual operated supply and waste transport:

- high level of adherence to delivery dates at supply and waste transport,
- potentiality to enlarge the route of transport,
- efficient assignment of staff at the system interfaces,
- simple modification of the transport routes by dint of CAD-tools and teaching.

AGVs facilitate the supply and waste transport between:

- care stations,
- kitchen,
- pharmacy,
- (purchase and waste) storage and
- laundry.

The components of the most common AGVs are:

- (drive–under) tractors
- (roll-on) transport containers,
- an automatic control device,
- a charging station to charge the drive–under tractor batteries automatically,
- horizontal routes of transport with floor installations,
- lifts as vertical routes of transport,
- rooms with transmit- and receive stations on the units and departments (AGV-room) and,
- haulage roads as container caches.

Note: The most common systems are guideline-bound (inductive, mechanical or optical reflection). The for this necessary expenditure led to develop guideline-free guidance.

Abb. 17 Drive-under tractor with roll-on container

It is recommended, that the lifts as vertical transport routes are only applied by the AGV-tractors to allow for safe transport under industrial and sanitary safety aspects. On the same reasons, the horizontal routes of transport should also be located in closed areas. If a HCFs doesn't possess lifts for sole utilisation by the AGV (e.g. the AGV was installed supplementary), the simultaneous use of lifts by persons and tractors must be excluded.

Tab 36 Exemplary technical specifications of an AGV

Load carrying capacity	400 kg
Size of the lift platform	960 x 600 x 330 mm (h x w x d)
Whole dimensions (including drive-under tractor and roll-on container)	1.900 x 600 x 330 mm (h x w x d)
Drive power	0,50 kW
Maximum speed	1,2 m/s
Positioning accuracy	**+/-** 10 mm
Battery charging	Automatic
Type of battery	Lead-acid battery (24V /172 Ah)
Lift dimensions (cabin)	2.700 x 1.800 mm (h x w)
Source: [44]	

The rooms with the transmit- and receive stations on the units and departments (AGV-rooms) should be arranged close to the AGV-lifts to avoid the transport across the public corridors. Hence, the respective rooms with the transmit- and receive stations on the several levels should be arranged on the same place. The receive stations are furnished with lateral guide bars to facilitate the container positioning by the service personnel. The transmit- and receive stations in hygienic sensitive areas, such as operation theatres and intensive care units, should be separated by dint of a wall to prevent the pollution of new supply. Figure 17 shows the floor plan of a nursing ward (with app. 36 beds) including waste storage room, the AGV-lift and the AGV-room.

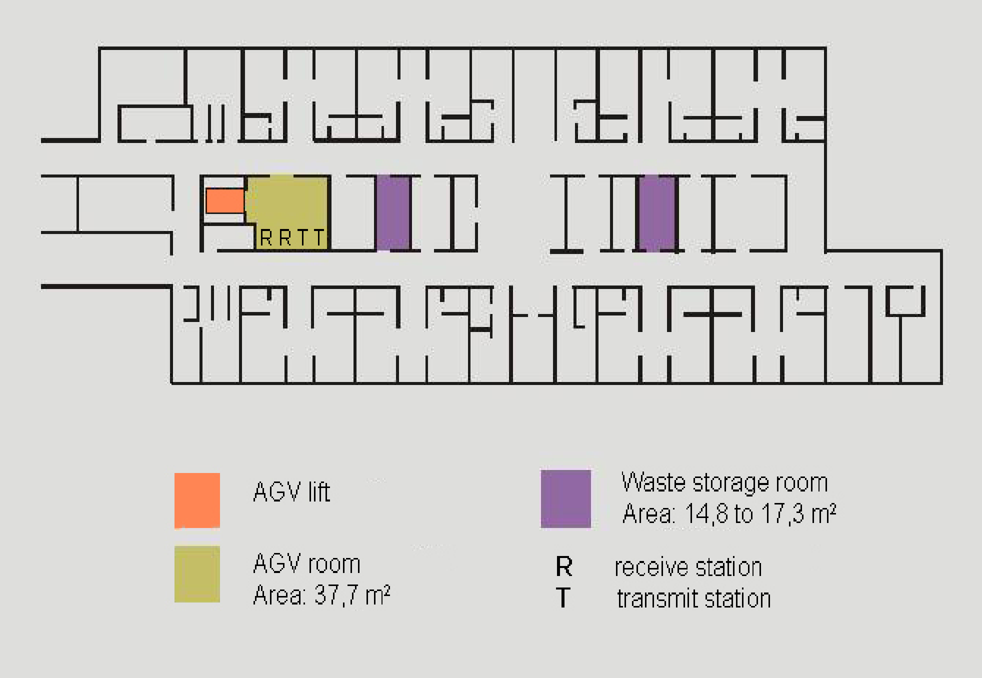

Abb. 18 Floor plan including waste storage room, the lift and the AGV room

The patient rooms are laterally, the working area including personal and work chambers (pure and impure) and the AGV-room is centrally arranged. In addition, a short as possible expenditure of time and way is realised by the arrangement of two impure work chambers including waste bins.

In this case, the AGV-room with floor space of app. 38 m^2 has two transmit- and two receive stations. The necessary quantity depends on the type of functional area and the number of beds. One station (transmit or receive) requires a floor of app. 1,8 m^2.

Following table shows necessary waste container transports per day (volume app. 1,1 m^3) of selected functional areas calculated in the planning phase of an university hospital.

Tab 37 Necessary waste container transports per day of select functional areas

Functional area	Transports per day
Ward (36 beds)	3
Ward (60 beds)	6
Endoscopy	2
Operation theatre	18
Institute of Radiology	1
Ward of bone narrow transplantation (app. 28 beds)	6
Pharmacy	6
Canteen	1
Source: [42]	

Due to the different uses of the transportation containers and the therefrom dependent requirements at their execution, three different container types may be differentiated:

- waste transport container,
- purchase and storage container including inserted baskets and
- universal containers.

The waste has to be only transported in special closed waste containers to meet hygienic and aesthetic concerns. All containers should be equipped with a special coding to prevent the container mix-up. The unintentional opening during the transport must be anticipated (e.g. by two point locking).

In the majority of cases, the transport containers are equipped with wheels, because a manual transport is furthermore necessary. The wheels are designed as swivel castors with directional lock. The front walls of the transport container and the corridor walls in the areas of transport should be equipped with current impact protection (made of hard rubber) to prevent the damage of the walls.

The reusable waste transport container are to clean with a disinfection effect to prevent the possible spread of infectious agents. Some HCFs use automatic washing plants for this purpose. It should be noted, that the application of these plants must not affect negatively the undisturbed AGV operation. In addition, these plants should ensure the sufficient drying of transport container.

In the case of reusable transport containers are cleaned manually, the disinfection must be effected before the containers are washed with water and cleaning agents. The bottom of the containers should be sloped and provided with a drain to prevent water residues in the inside. The drain is to be closed to prevent the discharge of fluids during the transport.

1.6.9 Off-site transportation vehicles and routing

Where there is no on-site treatment facility available, all HCW are to be transported to a regional treatment/disposal facility, as applicable to the respective HCW categories. Off-site transport of HCW can therefore be considered to be the movement by means of suitable designed vehicles from the point of storage, to the point of treatment/disposal outside the HCF. External transport of hazardous HCW must be in an uncompacted state as containerised at source, whilst general HCW may be in either an uncompacted or compacted state, depending on the volumes generated as well as the containers and vehicles used.

Dispatch documents should be completed before transportation, if necessary. In case of exportation, the consignee (the HCF) should have con-firmed with the relevant competent authorities that the waste can be legally imported and that no delays will be incurred in the delivery of the consignment to its destination.

General waste bags that are not in waste compactors may be placed directly into the transportation vehicle, but it is safer to place them in further containers (e.g. cardboard boxes or wheeled, rigid, lidded plastic or galvanised bins). This procedure results in higher disposal costs but has the advantage of reducing the handling of filled waste bags [43]. General waste generated in HCFs can be transported together with normal municipal waste in the same transportation vehicle, provided that waste contaminated with body fluids and egesta will not be treated or separated by hand before final disposal or incineration.

The vehicles transporting HCW should be equipped with a bulkhead between the driver‘s cabin and the vehicle body to retain the load if the vehicle is involved in a collision. The load should be secured during transport by a suitable system, internal angels should be rounded to prevent the destruction of waste bins and plastic bags, protective clothing, cleaning equipment, and disinfectant, together with special kits for dealing with liquid spills, should be carried in a separate compartment in the vehicle. The transportation chamber should be closed-topped and designed so that it is easy to steam-clean. The floor should be sealed to prevent leakage of fluids [43].

Vehicles transporting hazardous HCW should not be used only for the transportation of hazardous waste and should be provided outside with the international hazard sign. The usage of demountable trailers (temperature-controlled if required) are particularly suitable, as they can easily be left at the HCFs. If the storage time exceeds the recommendations or transportation time is long, special refrigerated containers may be used. Transportation of hazardous HCW needs to be controlled meaning that it should be ensured that the waste arrives at its destination. This can be achieved by a consignment note to be signed by the recipient of waste and returned to the HCF. Some national authorities such as Germany and U.K. regulate this matter by law.

Small and scattered HCFs that practise minimal programmes of health-care waste management should either avoid off-site transportation of hazardous waste or at least use closed vehicles to avoid spillage. As a minimum a trailer, tractor or small truck will be sufficient if the site is nearby. If the off-site facility is 2 or more kilometres away from the HCF, a larger truck will be required for transportation of potentially infectious waste and sharps. This truck may also be used to collect hazardous HCW from other HCFs. [41]

Further handling after departure from the HCFs should be prevented. If this is not possible, it should take place in adequately designed premises. [43]

The following statements should be valid, in particular in developed nations: Only companies authorised through registration with the regulatory authorities should transport hazardous HCW. The personnel should know how to counteract the risks involved in the transport. The exact transport charges should be clearly defined in the final account. The HCF should trace the correct and legal waste treatment and final disposal. The quantity details should be determined and evaluated and compared with data established in-house [45].

1.7 Treatment and disposal of infectious waste

1.7.1 Fundamentals

The aims of treatment and disposal of HCW must be to limit public health and environmental impacts by

- transforming the waste into non-hazardous residues by treatment
- containing the waste/residues to avoid human exposure
- containing the waste/residues to avoid dispersion into the environment [46].

The main objective of treatment must be the secure inactivation of obligate pathogens.

The high-temperature incineration of HCW is the safest method to inactivate pathogens – the resulting ash can be deemed to be sterile. The apprehension that non-inactivated microorganisms occur in the flue gas of incinerators is baseless [47]. It is a treatment method that is currently in use in many countries. For most facilities in developing countries it represents the only suitable process.

However, considerable environmental impacts are caused by improper incineration with insufficient technologies and without effective flue gas cleaning. Different investigations has shown that persistent organic pollutants (POPs) such as dioxins and persistent toxic substances such as mercury can travel long distances, bio-accumulate in living organisms, and pose significant ecosystem and human health risks, such as lung, laryngeal and other cancers. On this reasons the Stockholm Convention on POPs promotes the use of alternatives to incineration that avoid the generation of POPs (see separate section).

The alternative is the disinfection of infectious HCW, if no causative agents of transmissible spongiform encephalopathy and Creutzfeldt-Jakob disease are included.

The terms sterilisation and disinfection refer to microbial inactivation and are used often incorrect. Sterilisation is the complete destruction of all of microbial life and is not necessary. Disinfection is the reduction of microbial contamination, especially the diminution of disease-causing microorganisms or pathogens. Naturally existing pathogen microorganisms might still be found. Disinfection is technical easier to realise and cheaper. In addition, the complete inactivation of all of microbial life is not necessary for any waste. It is only practiced and obligate for surgical instruments and wraps. However, a uniform definition of the term disinfection in references lacks, especially concerning waste treatment.

In addition, the examination of disinfection efficacy is not defined uniform. But facilities are responsible for the sufficient disinfection efficacy. The WHO provides that a 99,99% inactivation of microorganisms may be expected [43]. The microbiological inactivation efficacy of disinfection plants must be inspected with microbiological tests.

In principle, disinfection can be carried out by means of hot air, moist heat (heated water, steam), ionising radiation (e.g. beta or gamma rays) or chemical substances (i.e. gases, aqueous solutions). Due to the special waste disinfection requirements not all of these processes are considered. As along with high costs additional expenses arise for the removal of the disinfectant amounts (e.g. ethylene oxide) remaining in the disinfected waste, a treatment with chemicals drops out of choice, especially in developing countries. Due to the small waste penetration depth, beta rays are also not very suitable for the disinfection. As a result of their unstable penetration and mixture, both processes cannot ensure a safe disinfection. The same is true for liquid or powdery disinfectants.

The disinfection by microwave irradiation represents another, newer disinfection method and works also thermally, preferentially as steam disinfection by heating of the water contained in the waste.

On above-mentioned reasons the appropriate and safe HCW-treatment methods are:

- incineration,
- cooking with water,
- steam disinfection or wet thermal disinfection (autoclaving and microwave irradiation).

Cooking with water is more a theoretical method. Treatment plants to cook the infectious waste are not common. The separation of the water and the waste is complicated to realise and complex. The considered treatment methods in this curriculum are therefore only the incineration and the wet thermal disinfection.

Irrespective from the method of treatment the number of pathogens surviving treatment depends on:

- the initial microbial count,
- the residence time,
- the intensity of the harming impact,
- the resistance of the microorganisms.

Figure 18 shows an idealised inactivation-graph of microorganisms with a uniform resistance, without protection factors at a permanent impact.

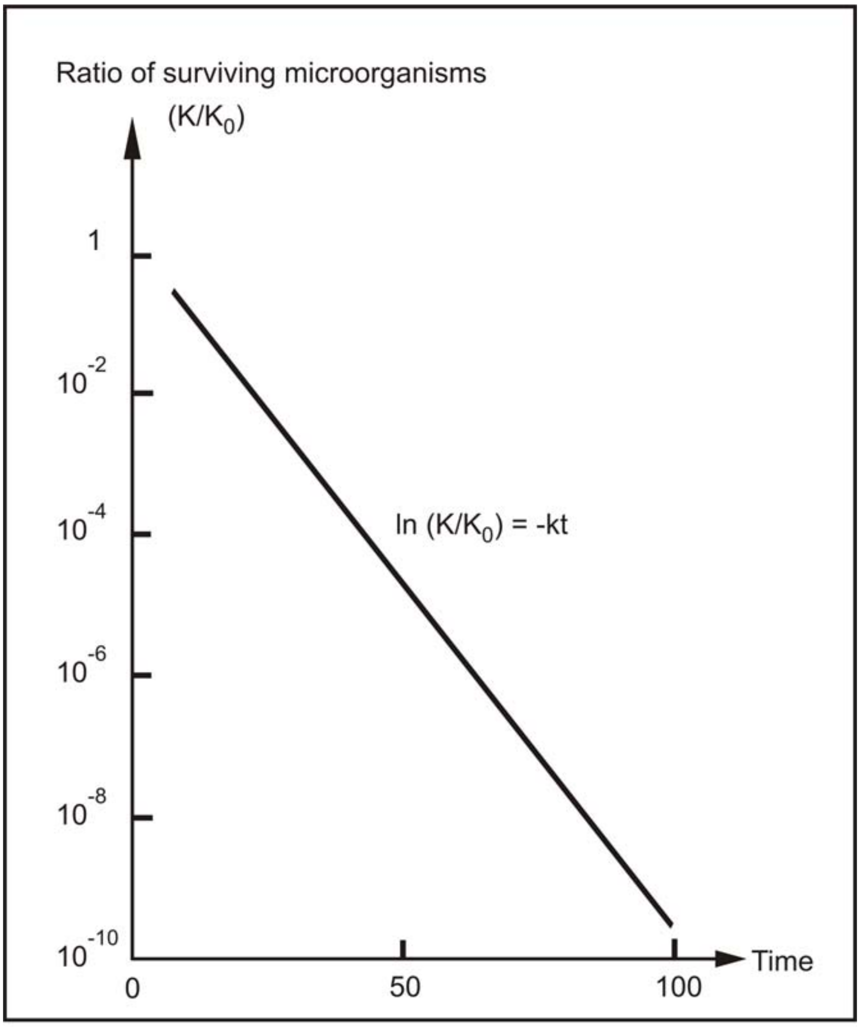

Abb. 19 Idealised inactivation-graph of microorganisms with a uniform resistance, without protection factors at a permanent impact

The depicted reaction kinetics is only true when the determinant medium (steam in case of steam disinfection) can directly affect the microorganisms at constant pressures and temperatures. However, the special configuration and substantial composition of the waste complicate an equal penetration with steam. A crushing of the waste or permanent movement or mixing can be helpful. However, crushing and mixing devices are partially accident-sensitive and space consuming.

As another precondition for a successful disinfection, most disinfection processes require the complete removal of all air from the material that is to be disinfected. During steam disinfection this is achieved by the repeated evacuation of the disinfection chamber, in doing so replacing the exhausted air or the air-steam-mix by steam flowing in from behind. There is a risk of co-exhausting pathogens that will escape the disinfection process. Hence, the exhausted air should be processed to and through bacteria-proof filters. Also the condensate that might accrue must be considered potentially infectious and should be led back to the disinfection chamber, as long as a safe disposal together with wastewater is not possible.

1.7.2 Options of treatment organisation

Basically, three possibilities exist to organise the treatment of HCW. These are, like above-mentioned:

- a treatment plant in every single HCF,
- regional or cooperative central treatment, supplemented by local treatment possibilities for remote facilities,
- treatment of the HCW in existing industrial or municipal plants (municipal waste incineration plants) [43].

Every possibility possesses specific advantages and disadvantages.

1.7.2.1 On-site treatment

On-site treatment plants are advisable when the HCFs are far away from each other and the road network is bad. Larger facilities can serve as collection and treatment station for small and widespread waste sources. Advantages and disadvantages of on-site treatment plants are shown in the following table.

Tab 38 Advantages and disadvantages of a decentralised treatment

Advantages	Disadvantages
• comfortable • reduction of the risks and nuisances that hazardous materials transportations pose to the public	• technical staff can be necessary for each facility • difficulties in authorities' control

1.7.2.2 Off-site treatment

Treatment methods that are preferable and optimal for large HCFs are possibly impracticable or not cost-effective for smaller facilities. Thus, treatment in regional or cooperative off-site treatment plants is a reasonable alternative for these small and financially weak facilities. Hospitals can join forces and treat their HCW in one central treatment plant with advanced control opportunities and a higher throughput. Local waste management enterprises that take over treatment and disposal duties are another option. Systems like these exist in several countries, on private as well as on municipal level.

When regional conditions argue for a centralised treatment of HCW, the advantages compared with decentralised processes are relevant especially in developing countries. The main advantages are:

- a better cost-efficiency in larger treatment plants,
- the capacity reserve can be provided more economic,
- an extension and enhancement of the treatment technology (e.g. flue gas cleaning) is easier to implement,
- if a privatisation of the disposal sector is aspired, it is easier to realise with one central plant compared to multiple small plants;
- authorities' control of the treatment plant is facilitated,
- an efficient process can easier be achieved in larger plants as small plants often don't have trained staff,
- HCFs don't have to employ technicians for the operation of their own plant.

One of the biggest disadvantages of off-site treatment or disposal is potential liability associated with improper disposal by waste haulers, occupational injuries during transport of the waste, and roadway accidents that may result in spills or injuries. Another disadvantage is the need to comply with yet another set of international, national, and local regulations for inter- and intra-state transport of hazardous waste (see section "Safe handling, storage and transportation").

Unfortunately, the HCF manager is often not informed of where their waste is being taken. This uncertainty can be removed by plant inspections, close contact with the operator or installing an on-site treatment technology, thereby eliminating long-range transportation of infectious waste and treating the waste close to the point of generation. [8]

The location for an off-site treatment plant must be chosen with care. Prior to that, the designed catchments area with all hospitals, the waste quantity and the exact position of the hospitals must be known. The selection of the location should base upon the following considerations and information:

- present and expected waste quantities of the individual facilities in the catchments area,
- accessibility of the facilities from the selected location (road conditions, distances and transportation times),
- necessity of intermediate collection points in case of long transportation times,
- future change of waste quantity and composition related to changes in facilities' capacities,
- assessment of the expected (additional) environmental impact,
- geographical (and geological) suitability of the location.

When selecting a treatment location, the minimisation of transportation times should be the most important factor. The implementation of a waste management plan is indispensable for data acquisition and analysis.

1.7.2.3 Situation in Germany exemplified

As in other industrial countries, the on-site incineration of HCW was the preferential choice in Germany. According to the size of the incineration plant, almost all the waste (including waste similar to domestic waste) was incinerated. However, following the legislation and implementation of the Federal Immission Protection Act (Bundesimmissionsschutzgesetz) in 1974 and the consecutive ordinances, most of these plants were shut down. Presently, most hospitals dispose of their infectious waste by mandating special waste management enterprises that combust it in hazardous waste incineration plants, complying with the state of the art.

In Germany, the costs for such a disposal of the infectious waste amount to approx. 0,60 € to 1,60 € per kg of waste. Additionally, the hospitals have to finance the necessary type-examination tested collection and transport container (3 to 4 € per 60-litre-bin).

On-site disinfection plants such as steam disinfection plants are only partly in use in some larger hospitals, as they tend to be uneconomical for smaller facilities.

1.7.3 Incineration

Incineration is an oxidation process that along with a massive decrease in volume and mass reduces organic combustible substances to inorganic substances and inactivates pathogens. Because it represents the simplest treatment process, it is well established in developing countries. Apart from basic constructions (incineration in drums) facilities exist that are equipped with better technologies (e.g. multi-chambered incineration with subsequent flue gas cleaning). If necessary, further treatment has to be provided for accruing flue gas and wastewater.

Emissions from health-care waste incineration plants mainly consist of:

- particles (ash, carbon black),
- heavy metals,
- acidogenic flue gases,
- carbon monoxide,
- polycyclic aromatic hydrocarbons (PCPs, dioxins, furans).

Larger incineration plants can be equipped with energy recovery aggregates. While in cold climes the heated water can be supplied to the thermal system, the conversion of the thermal energy to electric power is suggested in warmer regions.

Incineration of waste from HCFs can only be efficient when the waste possesses special characteristics. More precisely, the net calorific value of the waste should be at least 2,000 kcal/kg (8,730 kJ/kg) for incineration and at least 3,500 kcal/kg (14,640 kJ/kg) for pyrolytic incineration [43]. Characteristics that the waste should possess in order to be incinerated properly are listed in Tab 39.

Tab 39 Characteristics of waste to be incinerated

Net calorific value	At least 2,000 kcal/kg (8,370 kJ/kg) for single-chamber incineration, at least 3,500 kcal/kg (14,640 kJ/kg) for pyrolytic incineration
Combustible materials	> 60 %
Non-combustible solid materials	< 5 %
Non-combustible fine materials	< 20 %
Moisture content	< 30 %
Source: [43]	

In Europe, a temperature of more than 1.100 °C has to be complied within the second chamber for the incineration of waste with chlorous organics content over 1 % [European Parliament Directive 2000/76/EC].

Following table shows the advantages and disadvantages of HCW-incineration.

Tab 40 Advantages and disadvantages of HCW-incineration

Advantages	Disadvantages
• good disinfection efficiency • drastic reduction of waste volume and weight	• efficiency of chemical + pharmaceutical waste treatment good for rotary kiln, ~95% for pyrolytic incinerator, very limited for lower temperatures • toxic emission to air if no control devices • maintaining temperature levels (and efficiency) in field incinerators is difficult • usually high costs for high temperature incineration
Source: [43]	

Abb. 20 Health-care waste incinerator

1.7.3.1 Pyrolytic incinerators

Technology

Pyrolytic incineration that is also known as thermolysis, double-chamber-incineration or controlled air incineration is an incineration technology that complies with hazardous materials regulations in the European Union as well as in the United States. However, it is not a new treatment technology, as wide experiences exist in the petrol and chemical industry. A pyrolytic incinerator consists of two chambers – the pyrolytic chamber and the post-combustion-chamber.

With the aid of a burner and in oxygen deficient conditions the waste is treated thermally in the pyrolytic chamber at temperatures around 800 to 900 °C. As a result, ash and gases accrue. The waste is fed to the pyrolytic chamber in containers or bags.

The generated gases are combusted in the second chamber, this time with surplus oxygen at temperatures from 900 to 1200 °C [43]. This type of incineration assures a massive decrease in emissions.

Characterisation

Pyrolytic incineration represents an efficient process for the treatment of infectious (as well as sharp materials) wastes. All microorganisms are inactivated at the existing temperatures.

Tab 41 shows all relevant characteristics of the pyrolytic at a glance.

Tab 41 Characteristics of pyrolytic incineration

Appropriate types of waste	Infectious waste, pathologic waste, sharps
Inappropriate types of waste	Genotoxic substances, nuclear waste, PVC, pressurised containers, waste with a high heavy metal content
Type of treatment	Temperature (800 to 900 °C)
Throughput	200 kg/d – 10 Mg/d
Additional remarks	Relatively high investment costs and running expenses Trained staff is necessary
Source: [3]	

A decrease in dioxin and furan emissions is only achieved in oxygen deficient conditions. However, the oxygen supply by the waste stream can hardly be ruled out regarding to health-care waste and waste of a similar type. The incineration conditions must strictly be complied with, as packaging materials from halogenated plastics (e.g. PVC) are no doubt in use in HCFs. The combustion of these plastics can result in dioxin emissions when the temperatures in the post-combustion-chamber are insufficient.

Operation and equipment standards

To prevent the generation of harmful solid or volatile compounds, optimal incineration conditions are necessary. Thus, the plant should meet the following criteria [43]:

- Both chambers must be resistant to corrosive gases and waste.
- The supply installation should allow the feeding with packed waste (containers or bags). The size of the ash-empty opening should be chosen dependant on the non-combustible waste content. A possibility for the ash to cool down is necessary.
- In order to provide waste retention periods of one hour, the pyrolysis chamber must be selected big enough. It should be equipped with guide plates to guarantee the mixture of the waste with the air supply.
- Temperatures in the post-combustion-chamber should reach a minimum of 900 °C at a gas retention period of at least two seconds; air supply with oxygen and high turbulences must be guaranteed.
- The incineration process should be operated, controlled and if necessary regulated by a central control station. A permanent monitoring of the functional efficiency as well as of different parameters (temperature, air supply, fuel supply) should be given (see Abb. 21).

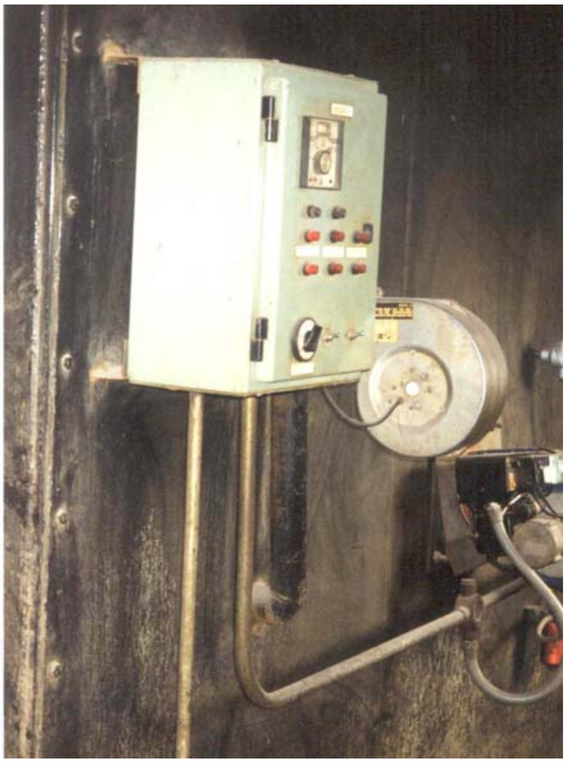

Abb. 21 Instrument panel of a health-care waste incinerator

A trained technician is essential for the permanent control of the incineration process. This control is not only necessary to minimise pollutant emissions or increase treatment efficiency but also to reduce the maintenance costs and to extend the lifetime of the equipment. Large plants (throughput more than 4 Mg/d) need a permanent monitoring by a technician that was specially educated in waste management [43].

Both chambers must be procedural harmonised exactly. When the waste is incinerated too fast, the retention period of the gas in the post-incineration-chamber rises, thus causing an increase in carbon black and slag generation. On the other hand, the flow rate of the gas decreases when the incineration in the pyrolytic chamber is too slow. While this leads to lower air pollution, the capacity decreases and the fuel consumption rises. [43]

If possible, central pyrolytic incinerators should be operated in existing industrial zones. These areas are likely to possess good transport connections and energy networks. The plant must have a minimum distance of 500 m to human settlements [43].

Costs

Apart from investment and maintenance costs, expenses for the required fuels (oil or gas) arise for the pyrolytic process. The consumption is around 0.03 to 0.08 kg/kg waste for oil and around 0.04 to 0.1 m^3/kg waste for gaseous fuels. [3]

Tab 42 shows the existing market prices regarding to estimates of the arising expenses in Europe in 1996.

Tab 42 Investment costs for pyrolytic incinerators in Europe in 1996

Technical equipment	**Investment costs (in 1000 US$) for different capacities (Mg/d)**				
	0.4	1	2	4	8
Without energy recovery and flue gas cleaning	50	100	120	150	230
With energy recovery, without flue gas cleaning	100	180	230	340	570
With energy recovery and flue gas cleaning	300	400	480	600	780
Source: [43]					

1.7.3.2 Rotary kilns

As with pyrolytic incineration, the principle of incineration in rotary kilns is known from the industry. They are commonly in use in the chemical and cement industry.

Abb. 22 shows a rotary kiln plant operating in Germany with a sophisticated flue gas cleaning.

Technology

The incineration takes place in a rotating kiln with an inclination up to 10 °. Due to this inclination of the kiln and the rotating movement, the waste that is supplied on top is permanently mixed and supplied with oxygen during the incineration process. The kiln is powered by an electric engine spinning the tube at a speed of 2 to 5 times per minute [43]. The ash is emptied at the bottom.

Generated gases end up in the post-combustion-chamber where gaseous organics are combusted at high temperatures.

Characterisation

Rotary kilns are suitable for the incineration of infectious and pathologic wastes as well as chemicals and pharmaceutical products. The high temperatures of 1.200 to 1.600 °C lead to the inactivation of all microorganisms and, if applicable to the destruction of cytotoxic waste. The following table shows the most important characteristics of incineration in rotary kilns.

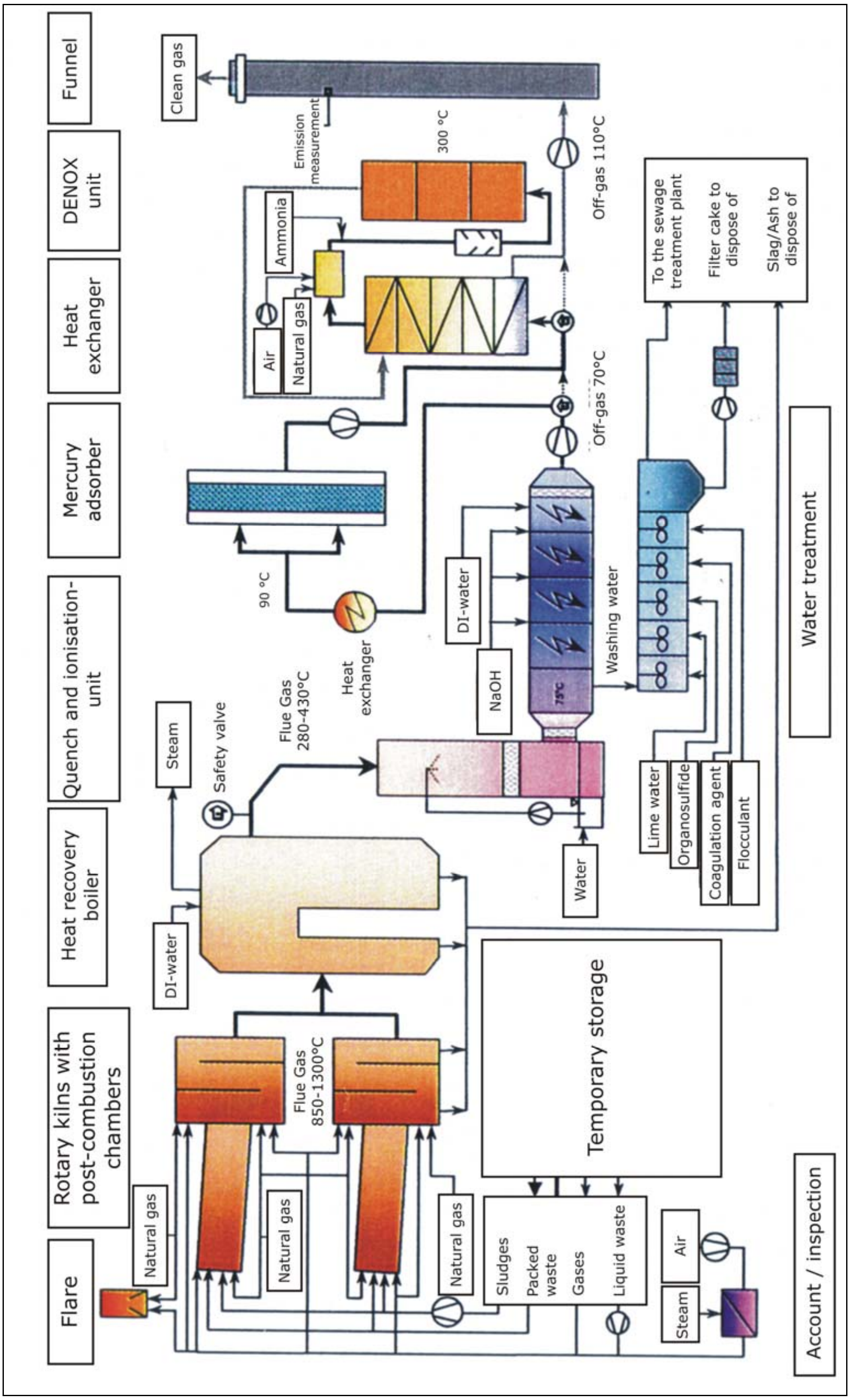

Abb. 22 **Design-diagram of a rotary kiln to incinerate hazardous wastes**

Tab 43 Characterisation of rotary furnace incineration

Appropriate types of waste	Infectious waste, sharps, pathological waste, chemicals, cytotoxic waste
Inappropriate types of waste	Radioactive waste, pressurised containers, waste with a high content of heavy metal
Type of treatment	Temperature (1.200 to 1.600 °C)
Throughput	500 kg/h – 3 Mg/h
Additional remarks	High investment costs and running expenses Trained staff is necessary
Source: [43]	

Operation and equipment standards

Corrosive wastes or combustion products tend to erode the inner layers of the kiln and the post-combustion-chamber. Hence they have to be heavily resistant against corrosive impacts. Other operation and equipment standards are quite similar to those of the pyrolytic incineration (see section 1.7.3.1):

- The retention period in the post-combustion-chamber should be at least 2 seconds [43].
- A specially trained technician should permanently monitor at least larger plants.
- A permanent monitoring of the functional efficiency as well as several parameters (temperature, air supply, fuel supply) should be given (operation and control panel).

As any other large treatment plant, central rotary furnaces should preferably be operated in existing industrial zones. The distance to human settlements has to be at least 500 m [43].

Costs

Along with high investment and operating costs, additional costs arise for the required fuels (oil or gas) and for electric energy. Maintenance costs can partly be enormous, as corrosive wastes and combustion products can erode the interior of the incineration chamber, making repairs or even complete replacements necessary.

1.7.3.3 Incineration in municipal incinerators

The incineration of HCW in municipal incinerators should always be considered first as an option if one is located reasonably close to hospitals.

The heating value of HCW is significantly higher than that of domestic refuse and the incineration of HCW in these plants can cause some operation troubles. But the introduction of relatively small quantities of HCW will not affect the operation of a municipal incinerator [43].

Incinerators used for incineration of domestic refuse are usually of a double-chamber design. The operating temperature amounts to 800°C in the combustion chamber and to 1000-1200°C in the second chamber.

To prevent human exposure and to ensure that the waste is efficiently treated certain precautions must be taken [46]:

- transportation of waste only in appropriate and undamaged packaging (checking before removal),
- availability of facilities for cleaning and disinfection of transportation equipment at the incineration site,
- HCW should be placed into bunker but loaded directly and automatically into the furnace to prevent risk of waste bags being damaged by transportation with crane,
- maximum storage time should amount 24 hours if no cooling facility is available,
- the combustion efficiency must be at least 97% during incineration of health-care waste,

Wastes which are not suitable in principle for incineration, such as pressurised containers, must also not be included in the HCW which is incinerated in municipal incinerators.

1.7.3.4 Incineration options for small HCFs

In developing countries, especially the smaller HCFs don’t possess the required funds and the know-how for the installation and operation of large technical complex treatment plants. Hence, inexpensive techniques to treat microbiological critical HCW should be made available for these facilities.

Provided that they are operated properly, small incinerators with only one incineration chamber can destroy all microorganisms in the waste, thus massively reducing the infection risks that infectious waste represent. Especially in case of outbreaks of regional epidemics, simple treatment processes are necessary. These incinerators are operated on demand and require only a short instruction of the staff.

Currently, two different types of incinerators for small quantities are in use in developing countries:

- incineration in (used) drums,
- incineration in brick incinerators.

Characterisation

The temperatures arising in simple incineration facilities are by far smaller than in pyrolytic incinerators or rotary kilns. For the single-chambered incineration temperatures are situated around 300 to 400 °C. However, they guarantee a reduction of microorganisms of 99 %. Besides the inactivation of the pathogens, a massive reduction in mass and volume takes place. Lower temperatures (under

200 °C) don't assure the destruction of chemical or pharmaceutical products. Hence, simple incinerators with low temperatures should only be applied to the incineration of infectious wastes. The environmental pollution is high due to the lacking flue gas cleaning and the incineration process that is difficult to control. The following table shows all characteristics of the single-chambered incineration.

Tab 44 Characterisation of the single-chambered incineration

Appropriate types of waste	Infectious waste, sharps, pathological waste
Inappropriate types of waste	Radioactive waste, pressurised containers, pharmaceutical and chemical products, inorganic waste, halogenated plastics (e.g. PVC)
Type of treatment	Temperature (300 to 900 °C)
Throughput	100 kg/d – 400 kg/d
Additional remarks	Only little training necessary Very low investment costs and operation expenses Massive environmental pollution
Sources: [43], [48]	

Operation standards

The brick incinerators or drums should be preheated to ensure a quick and sufficient incineration before the waste is loaded (preferably in closed bags). Until the waste is combusted entirely, wood must be fed to the fire. After the incineration process is completed, all of the ash must be collected and buried safely.

Drum incinerator

The incineration in used drums (also: field incinerator) is the simplest treatment process for infectious waste. It should just be applied to the incineration of infectious waste and only if other treatment processes are not available. The generated exhaust gases and flue ashes contribute massively to the pollution of the environment.

Abb. 23 shows a pictured tutorial for the construction of an incineration drum for infectious waste.

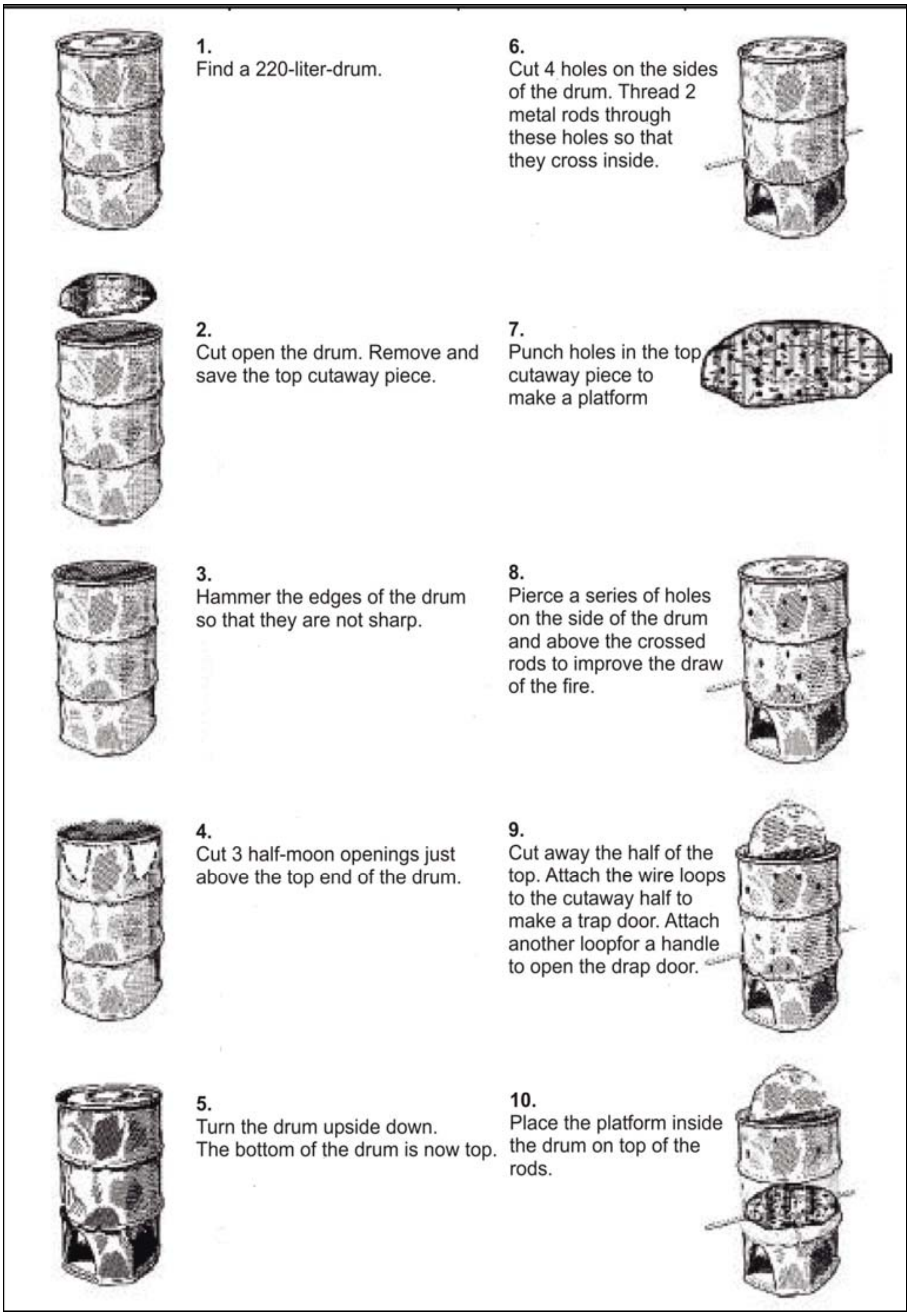

Abb. 23 Construction a drum-incinerator

According to the incineration in used drums, pre-cast drum-shaped single-chambered incinerators are available on the market. They ensure considerably higher combustion temperatures and throughputs. Two of these kilns made out of steel are shown in the following figures.

Abb. 24 VULCAN and SICIN incinerator

Due to their small measures (VULCAN: l*w*h: 1 m * 0,75 m * 2,5 m) and the low transport weight of approx. 800 kg they are especially suitable for the outbreak of regional pandemics. In Tab 45 the investment costs and operation expenses as well as other characteristics of the VULCAN type are listed.

Tab 45 Characteristics and costs of the VULCAN-incinerator

Investment costs	6,000 US$
Operation expenses	500 US$/year
Throughput	400 kg/d
Incineration temperature	900 °C
Approximate costs	2 - 8 US$/kg waste
Source: [48]	

Brick incinerator

Incineration in small kilns made of bricks or concrete is another possibility to treat small amounts of infectious waste. They are handled similar to the above-mentioned incineration drums. Special incinerators, e.g. the brick kiln developed at De Montfort University, are operated with oil as secondary fuel. Thereby, compared to the use of wood, higher and more constant temperatures can be reached. To reduce the generated emissions, the “De Montfort-incinerator” is equipped with a post-combustion-chamber.

Tab 46 shows investment costs and operation expenses as well as the most important characteristics of a brick incinerator with fume outlet (type De Montfort). The arising expenses for oil or gas and waste containers are already included.

Tab 46 Characteristics and costs of the De Montfort - incinerator

Investment costs	500 - 2,000 US$
Operation expenses	450 - 3,500 US$/year
Throughput	12 - 50 kg/h
Incineration temperature	700 - 800 °C
Approximate costs	2.5 - 12 US$/kg waste
Source: [48], [49]	

The different designs of the De Montfort-incinerator bears the designation “Mark”. The designs have been subject to regular improvements and modifications. At present the Mark 7, the Mark 8a and the Mark 9 are the current models.

Following figures show a photo and a draw of the De Montfort-incinerator Mark 8a. In Tab 47 the needed materials for installation of Mark 8a are listed.

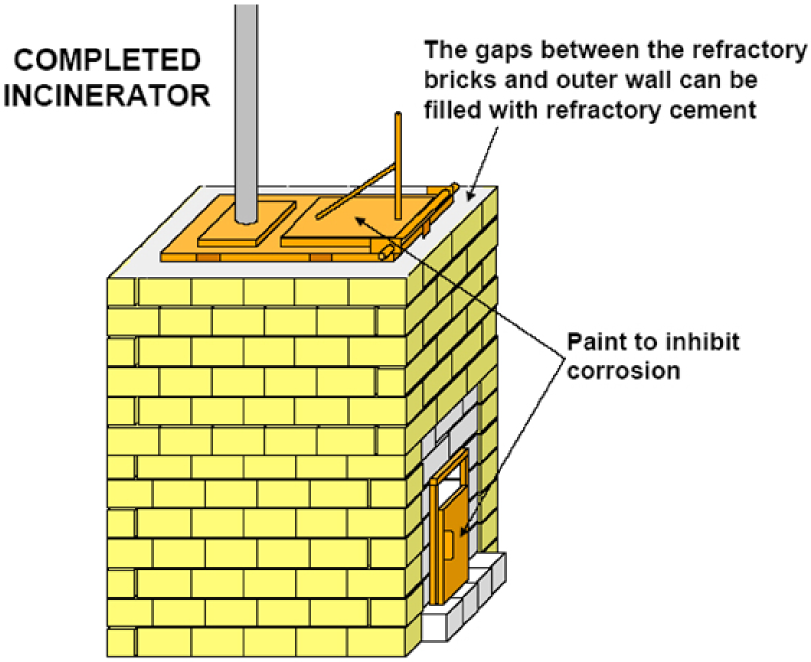

Abb. 25 **De Montfort-incinerator Mark 8a**

Tab 47 **Materials needed for installation of Mark 8a**

Item	**Dimensions**	**Quantity**
Fire bricks	230x116x76 mm	300
Cement (Portland)		250 kg

Ballast (for concrete base)		500 kg
Sand		1000 kg
Fire cement (high alumina)		100 kg
Rolled steel angle mild steel	40x40x3 mm thick	42 metres
Rectangular section mild steel	75x75x3 mm wall thickness	2 metres
Flat sheet (mild steel)	2400x1200x3 mm thick (app.)	1 sheets
Mild steel pipe	150 mm diameter x 3 mm thick (app.)	3 metres
Welding rods (mild steel)		60
Steel cable	5 mm 7 strand	40 metres
Turnbuckles	M8 x 150 mm long	4 (not essential)
Rolled steel angle (mild steel)	50x50x3 mm thick	6 metres
Fuel tank with tap.	2 litres capacity approx	1
Fuel pipe, steel	350 mm long x 6 mm diam.	1
Fuel pipe flexible	2 metres x 6 mm ID	
Bolts with nuts and washers	10 mm x 75 mm long	24
Wire mesh	Any fine gauge	loose fill
Source: [49]		

1.7.3.5 Regulations affecting incinerators and emission standards

Incineration of (health-care) waste is contested. The ash as the result of incineration can be toxic and the gaseous above-mentioned emissions, especially dioxins, can cause significant health impacts such as cancer. Dioxins are created during combustion in the presence of chlorinated waste such as polyvinyl chloride plastic.

The EPA has 1997 identified HCW incineration as the third largest source of dioxin air emissions and as the contributor of about 10% of the mercury from human activity in the USA [50].

Emission limits

On the mentioned reasons a lot of nations created regulatory emission limits. If these are not available, it is in order to resort to existing emission standards on Europe (see table 46).

Tab 48 Regulatory limits for pollutant emissions from incinerators in Europe

Emission	Daily average (mg/m^3)	Hourly average (mg/m^3)	4-hour average (mg/m^3)[a]
Total dust	5	10	-
Total organic carbon	5	10	-

Chlorine compounds	5	10	-
Fluorine compounds	1	2	-
Sulfur oxides as SO_2	25	50	-
Nitrogen oxides as NO_2	100	200	-
Carbon monoxide	50	100	-
Mercury	-	-	0,05
Cadmium and thallium	-	-	0,05
Lead, chromium, copper, and manganese	-	-	0,5
Nickel, arsenic	-	-	0,5
Antimony, cobalt, vanadium, and tin	-	-	0,5
Dioxins and furans	-	-	0,1
Oxygen content	at least 6% at any moment		
[a] Measurements made at standard temperature and pressure			

Incinerators generally cannot meet modern emission limits without emission controls [48]. The flue gas cleaning must be done in at least two different stages:

- de-dusting – to remove solid elements and
- washing with alkaline substances to remove hydrogen, halides and sulphur-oxides.

In this regard, it is very relevant that the optimal adjustment of the combustion conditions and the avoidance of the use PVC-materials are the best means of keeping production of toxic gases to a minimum.

Stockholm Convention

The international Convention on the Elimination of Persistent Organic Pollutants (POPs) was signed in Stockholm, Sweden, in May 2001 and entered into force in May 2004 (151 signatories). Article 5 requires that countries eliminate the generation of POPs. POPs are toxic and persistent organic hazardous substances. The collective term includes pesticides and industrial chemicals as well as harmful formulants such as extreme dangerous dioxins and furans originating as by-products of industrial processes or by combustion Appendix C of the convention lists medical waste incinerators among the main sources of dioxin in the environment.

One aim of the convention is that countries will be required to develop and implement action plans within two years to address the release of dioxins and furans. POPs are not generated when treating HCW using non-incineration technologies. Therefore countries will be best served in preparing for compliance by identifying and actively pursuing cleaner technologies to replace medical waste incinerators. Since many small incinerators cannot meet many environmental standards, promoting their use in developing countries would entail special exemptions or immunity from compliance thereby undermining the enforcement of environmental regulations. [51], [52]

Only highly equipped incinerators with air pollution control equipment and operational practice specifically designed to minimise dioxin formation and release could meet the demands. [48]

Formation of dioxins and furans from small-scale incinerators

Dioxin and furans are released to air via chimney exhaust and fugitive releases. Fugitive releases are e.g. air leaks when charging the incinerator with fuel or waste. Dioxin and furans also may be contained in bottom ash, in fly ash, and other dusts and in water and sludge discharges if a wet scrubber is used to treat flue gases. In combustion, dioxins and furans are formed by either

- so-called “de novo” synthesis from dissimilar non extractable carbon structures, and
- by precursor formation/reactions via aryl structures derived from incomplete aromatic oxidation or cyclization of hydrocarbon fragments. [48]

Generally, formation is given by following pre-conditions:

- the presence of a carbon surface or structure (e.g. fly ash),
- organic or inorganic chlorine, copper or iron metal ions (serving as catalysts),
- an oxidising atmosphere, and,
- ideally, a temperature range of 250 – 450° C [53].

The quantity of dioxins or furans generating depends on many factors, including:

- chemical and physical characteristics of the waste (organic carbon, chlorine, ammonia, amines, metals, moisture, sulphur).
- combustion conditions (the availability of oxygen, chlorine, other precursors/catalysts, temperature, time, mixing/turbulence, reactor materials). [48]

Emission standards for small incinerators

Small-scale low cost incinerators will not meet modern emission standards for many pollutants, e.g., dioxin/furans, monoxide, carbon, particulate matter, hydrogen chloride, and possibly several toxic metals. Emission standards can only be met by use of air pollution control equipment (removing particles, acid gases, etc.), combustion process monitoring (temperature, flow rates, etc.), and process controls (waste, fuel, air flows). These technologies are very expensive and will greatly increase the cost of incinerators, and they need careful operation, regular maintenance, and well trained operators.

However, there are some operational practices that will lead to emission reduction, e.g.:

- rigorously segregation of materials made of PVC,
- the incinerator should be built according to recommended dimensions
- exclusive usage of appropriate construction materials,
- the chimney must be clear of excessive soot.
- the incinerator should be preheated adequately before loading,
- supplementary fuel is available in sufficient quantity to maintain the burning temperature above 600° C.

National emission limits and other requirements should include the use of approved incinerator designs that can achieve appropriate combustion conditions (e.g., minimum temperature of 800° C, minimum chimney heights); appropriate siting practices (e.g., away from populated areas or where food is grown); adequate operator training (including both classroom and practical training); appropriate waste segregation, storage, and ash disposal facilities; adequate equipment maintenance; managerial support and supervision; and sufficient budgeting. [48]

1.7.4 Disinfection methods

1.7.4.1 Steam disinfection plants for larger facilities

Principle

Steam disinfection (or wet thermal disinfection) is based upon the treatment of (shredded) waste with steam under pressure and at high temperatures. During the last 100 years, it has proven reliable for both disinfection and sterilisation. Larger facilities for steam disinfection or sterilisation are known as autoclaves.

Due to the good conductivity and the high energy content of water (in addition to the required heating energy it also contains evaporation heat in terms of steam), steam disinfection features a good efficiency. However, these advantages only show up, if the steam is saturated, i.e. balanced with its liquid phase, and no air impurities exist. Thereby, the saturation pressure is directly dependant on the steam temperature. Tab 49 shows several steam temperatures and corresponding saturation pressures.

Tab 49 Saturation pressures of steam at different temperatures

T [°C]	100	105	110	115	120	125	130	135
p [bar]	1,01	1,21	1,43	1,69	1,98	2,32	2,70	3,04

Air inclusions might be the reason if higher pressures than the above-mentioned saturation pressures occur. Starting from a content of 10 %, air and other external gases massively interfere to the germ [54]. That's why air inclusions are the most common reasons for an insufficient disinfection. Especially when dealing with waste from HCFs, consisting of a large number of hollow parts made of material impermeable to steam, these difficulties have to be considered. The destruction of closed containers can be achieved by fractionated and repeated air-evacuation in conjunction with additional steam supply. This part of operation is mostly a component of the programme sequence.

The theoretical contact times depending on temperature needed to achieve disinfection are given in following table. The most of the plants work with higher temperatures and longer contact times because more time may be needed for steam to penetrate certain waste components such as microbiological cultures.

Tab 50 Theoretical contact times depending on pressure and temperature needed to achieve disinfection

Contact time	Pressure	Temperature
20 minutes	2 bar	121°C
5 minutes	3 bar	134°C

In Germany, several different steam disinfection processes have been licensed by the Robert-Koch-Institut. At residence times of 8 to 25 minutes the steam temperatures range from 100 to 134 °C.

Technology

In the majority of cases the treatment takes place in a cylindrical reaction vessel made of steel. The supply with steam with the required pressure and the necessary treatment temperature can take place by different ways. Either the disinfection plant is connected to a steam generator or a junction to a steam pipeline is available. Both, the vessel and the steam generator, need to be pressure resistant (up to 6 bar) as well as capable to endure the high temperatures (up to 160 °C) [55]. The plant is equipped with a vacuum pump. During the disinfection process, pressure and temperature are permanently monitored to control the operation conditions and to be able to change them, if necessary. The operation control can also be automated (see figure 20).

The following process steps are necessary for the regular operation of a steam disinfection plant [56]:

- Waste collection and transport: Waste collection in specially marked steam-permeable bags. On-site transport in dimensionally stable and easy to clean and disinfect containers.
- Preheating of the autoclave: Steam is processed to the exterior wrapping of the autoclave.
- Feeding of the disinfection chamber: The waste bags are delivered into the disinfection chamber. Sometimes it is needful to use a loading device (see Abb. 28 Loading device of a steam disinfection plant). The doors are locked and sealed.
- Air evacuation: Air is evacuated with vacuum technology.
- Steam treatment: Steam is processed into the treatment chamber until the required temperature is reached. To keep the temperature level above this mark for the whole treatment, additional steam will automatically be processed to the chamber.
- Steam removal: By means of a condenser or by vacuum technology again, the steam is removed from the chamber.
- Discharge: An additional time span is required for the cooling of the treated waste.
- (Mechanical treatment: Before disposing of the disinfected waste at a landfill, it basically is shredded and compacted.)

Abb. 26 shows the pressure-time-diagram of a steam disinfection plant made in Germany which demonstrates the individual parts of the automatic programme. The programme sequence duration take 50-60 minutes at a dwell time of 12 minutes and a treatment temperature of 134°C. The disinfection chamber is evacuated five times in the run-up to disinfection. Pressure and temperature are constantly supervised during the disinfection process and are documented by means of a printer and a contemporaneous announcement in the control panel, in order to control the operating conditions and to change these if necessary. If the automatic programme sequence is interrupted, it is possible to operate the plant manually by trained personnel.

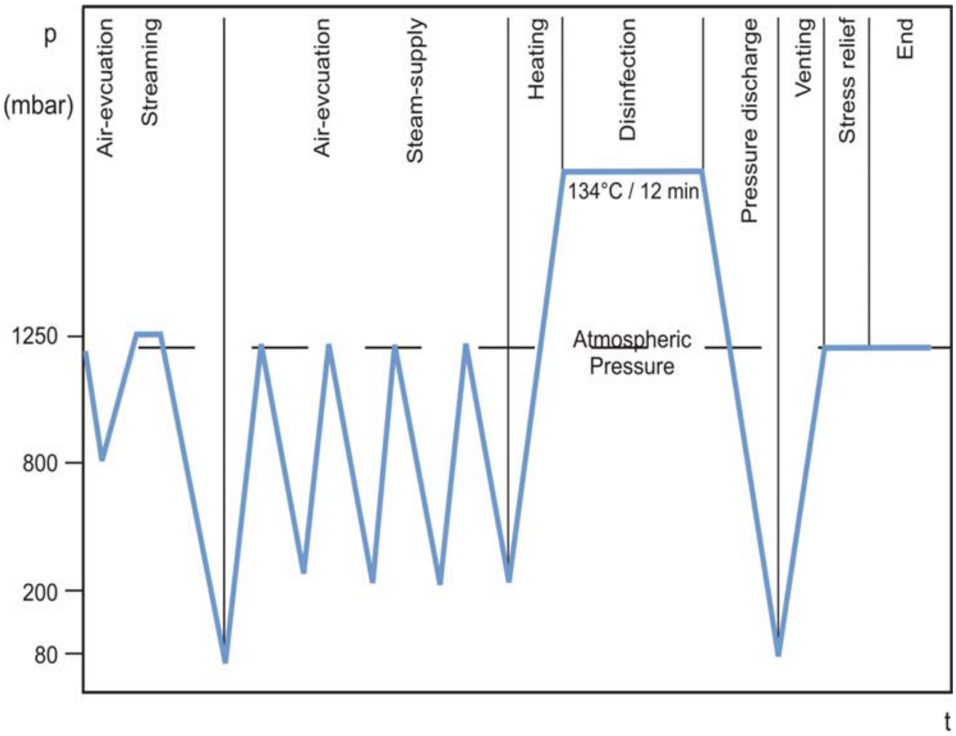

Abb. 26 **Pressure-time-diagram of an automatic programme sequence to disinfect HCW**

Abb. 27 shows a view of steam disinfection plant and the associated operation and control panel situated in a university hospital in Germany.

Abb. 27 **Steam disinfection plant and the associated operation and control panel**

Abb. 28 Loading device of a steam disinfection plant

Characterisation

The disinfection of HCW is similar to the disinfection of reusable objects from HCFs. Steam disinfection is only suitable for microbiological contaminated waste. For large animal carcasses and pathological waste as well as for chemical and pharmaceutical products steam disinfection is an inappropriate treatment process. Because of the necessary repairs, the relatively accident-sensitive shredder and mixing devices can lead to plant breakdowns. To a great extent, a sufficient disinfection performance is dependent on an orderly and permanently controlled process management. The waste containers must not be airtight during the treatment process. For the same reason, no hermetically sealed boxes of any kind may be among the waste. This is only admissible if they contain water or aqueous solutions. Hence, waste containers or bags made of steam-permeable material come into focus, as it would pose an infection risk to the staff if they open manually waste bins containing infectious waste.

Tab 51 shows the above-mentioned along with other relevant characteristics of steam disinfection plants for major sources.

Tab 51 Characterisation of the steam disinfection in larger facilities

Appropriate types of waste	Infectious waste, sharps
Inappropriate types of waste	Radioactive waste, pharmaceutical and chemical products, pathologic waste, larger animal carcasses
Type of treatment	Saturated steam
Throughput	20 l - 8 m^3 per cycle

Additional remarks	Trained staff necessary High investment costs and operation expenses for larger apparatus Minor environmental pollution
Sources: [55], [57]	

Sporadically, mobile steam disinfection technology is used in Europe and South America. Several HCFs can feed their infectious waste to this portable disinfection chamber.

The following table shows advantages and disadvantages of the disinfection with steam.

Tab 52 Advantages and disadvantages of steam disinfection

Advantages	Disadvantages
• steam disinfection is a well-known process with experiences of many years • the technology is easy to understand and is well adopted by hospital management and staff • it is available for different capacities, ranging from 100 kg/h to several Mg/h • when operated properly, emissions are very low • in comparison with other disinfection processes, the capital costs are low • several manufacturers offer the treatment system and the required accessories	• the volume can only be reduced when a shredder is used • every hard and large object might damage the shredder • if the waste contains chemicals, these are released – untreated – as exhaust gas, into wastewater or to landfill • if the waste is not subsequently dried, it will be massively heavier than before • the efficiency can heavily be reduced by containers that are impermeable to steam
Source: [56]	

Operation and equipment standards

As treatment processes equipped with shredders are susceptible to operation breakdowns, well-trained technicians should monitor and maintain steam disinfection plants. The persons in charge must be able to identify troubles. They should be responsible for load-documentation. Hence, only hospitals with sufficient financial and operational power may afford to construct and operate large steam disinfection plants.

Large steam disinfection plants are equipped with a programme to prove the pressure tight. This programme should be operated weekly. Thus the pressure tightness of the treatment chamber is controlled and an important condition for disinfection success is examined. The possible existing door seal is to be back-drew weekly also if the plant is idle.

The microbiological inactivation efficacy of a wet thermal disinfection technique must be routinely checked using mesophilic spore forming bacteria, such as the *Bacillus subtilis* or *Bacillus stearothermophilus.* The course of the test is as follows:

- execution under normal conditions,
- placement of the dried test spores in a steam-permeable and thermally resistant container (which shall be come into operation in the HCF),
- removal of the test organisms at the end of the cycle,
- inoculation of the test strips or discs inoculated in 5.0ml soybean–casein digest broth medium and incubation for at least 48 hours, at 30 °C for Bacillus subtilis and at 55 °C for Bacillus stearothermophilus; within 24 hours,
- sub-cultivation of any established growth onto appropriate media to identify the organism either as the test microorganisms or as an environmental contaminant. [55]

In Germany, additional regulations exist for the type test of steam disinfection plants (DIN 58948, DIN 58949).

With regard to the inspection date, three different checks are carried out:

- the testing after installation
- the periodical testing (very 6 months)
- the extraordinary testing.

The extraordinary testing should be conducted if new containers are used or if the composition of the infectious waste highly changed.

At discharge of treated waste malodour may leave the vessel. Hence, rooms which contain steam disinfection plants should be equipped with ventilating-system. By the same token, sensible areas, such as the kitchen, should not be nearby. The rooms should be additionally equipped with a floor train.

Costs

As with other treatment technologies, the investment costs and operation expenses of steam disinfection plants strongly depend on the necessary throughput. For this treatment process additional costs for electricity and water arise. The investment costs for vessel capacities from 20 l to 8 m^3 range from 50.000 to 200.000 US$ for the whole equipment. On the European market, a disinfection plant with a throughput of approx. 50 Mg per year costs around 100.000 US$. Operation expenses amount to approx. 400 US$ per Mg waste. [55]

Other authors state that, dependent on the throughput, investment costs for autoclave treatment range from 40,000 to 120,000 US$/(Mg*d) [58].

The costs to dispose of treated infectious waste are to add to the plain treatment costs.

1.7.4.2 Disinfection plants for minor sources

Non-incineration alternatives, such as large autoclaves, are readily available in industrialised countries, poor rural communities, especially in developing countries, have little or no access to these technologies.

So, HCFs in rural areas discard their waste along with general waste. This course of action increases the risk of spreading diseases, especially in poor communities that recycle materials from open dumpsites. Other HCFs use open burning to treat their waste. However, the inefficient burning of waste impacts the environment and consequently the public health by toxic by-products.

Efforts increase to make cost-efficient disinfection technologies available to small HCFs. Recently, the organisation *Health Care Without Harm* named a solar-powered disinfection plant designed for small capacities an alternative to incineration. For that reason, this modern and environmentally friendly process is presented in the following.

Principle

The disinfection plants work according to the steam disinfection principles, similar to autoclaves. By using highly effective solar panels the only necessary energy source is the sun.

Technology

Solar energy recovery takes place in copper pipes that are embedded in solar collector tubes. They contain water that is heated by the solar radiation. After the evaporation of the water, the steam is heated up to temperatures of 121 to 134 °C. The copper pipes are directly connected to a disinfection chamber. Two different types of construction applying the same principle were developed. The larger type has a capacity of 14 litres per disinfection cycle and possesses up to 20 collectors (Abb. 29). The smaller construction with a capacity of 1.5 litres, that is shown in Abb. 30, possesses one collector [59].

Due to highly effective solar collectors, these steam disinfection plants can also be operated all year long in cold regions.

Pressure and steam temperature control is carried out automatically. The inclination of the collectors of the large type can be changed to prevent overheating.

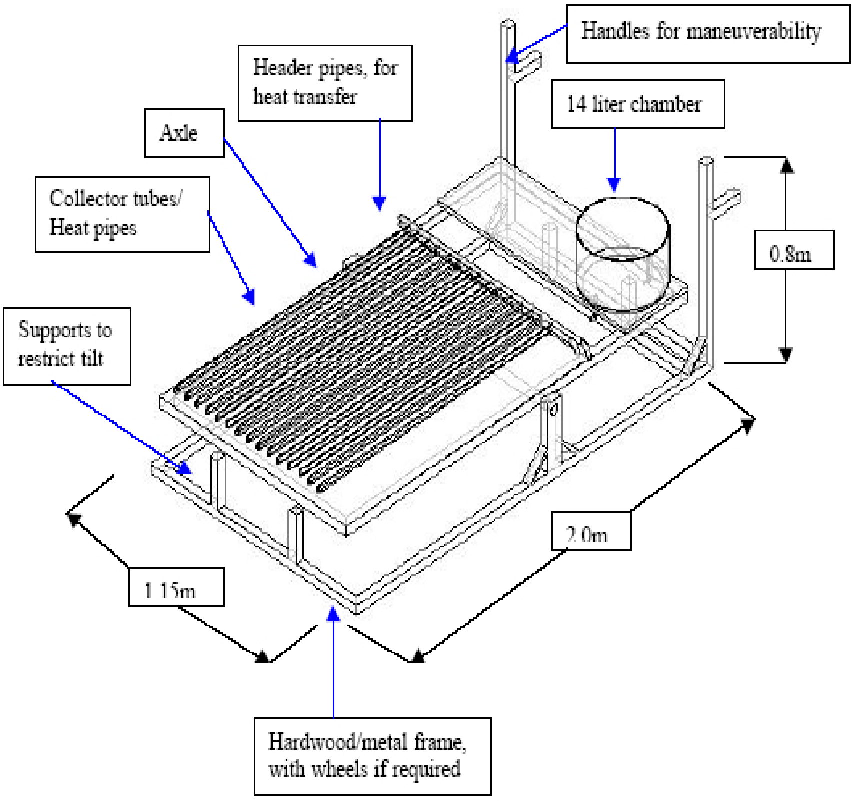

Abb. 29 **Large capacity device of solar-autoclave, Source: [10]**

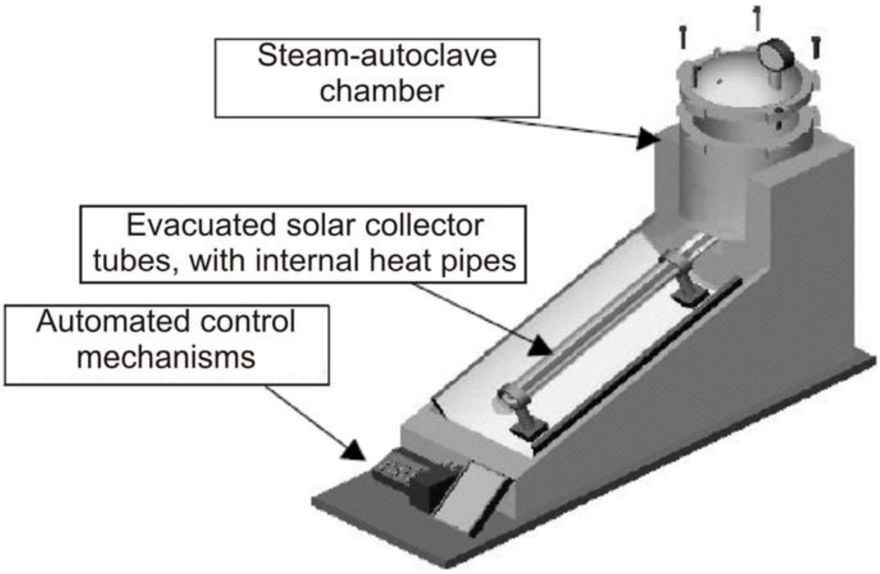

Abb. 30 **Small capacity device of solar-autoclave, Source: [10]**

Characterisation

Currently, only prototypes of solar-powered steam disinfection plants exist. Although they have successfully been tested regarding their microbiological inactivation efficacy, they still are in an experimental stage. Before this process is carried out regularly, more checks are necessary. The plants were originally developed for sterilisation. Hence, an orderly disinfection can be achieved at disinfection conditions. The inactivation efficiency of the solar-powered steam disinfection plants was checked with spores of *Bacillus Stearothermophilus*. As a result, a treatment time of 30 minutes under constant conditions and at a temperature of 121 °C was sufficient. That potential air was not evacuated from the waste seems to be a problem.

Tab 53 Characterisation of solar-powered steam disinfection

Appropriate types of waste	Infectious waste, sharps
Inappropriate types of waste	Radioactive waste, pharmaceutical and chemical products, pathological waste, animal carcasses
Type of treatment	Saturated steam at a temperature of 121 °C
Throughput	1.5 or 14 l per cycle
Additional remarks	No trained staff necessary Very low investment costs and operation expenses Minor environmental pollution
Source: [10]	

Costs

Currently, the disinfection plants are fabricated from precast and partially modified components.

Complete functioning plants are not yet available. Investment costs for the components amount to approx. 650 US$ for the small and approx. 1,700 US$ for the large type [59].

1.7.4.3 Microwave irradiation

Microwave treatment of infectious waste is an accepted disinfection process. Considering the disinfectant list of the Robert-Koch-Institut in Germany three different systems are licensed for the microwave treatment of waste. Partially, they are in use with special waste containers. In Austria, some microwave disinfection processes are licensed according to Ö-Norm, the Austrian equivalent to the German DIN.

Principle

The disinfection by means of microwave irradiation represents another type of thermal treatment. In contrast to steam disinfection, the necessary energy is not distributed via steam but applied as microwaves that generate the required temperatures in the interior of the waste mixture. Basically, the disinfection is not caused by the radiation but by the temperature rise, the supply of hot steam being the fastest way to inactivate microorganisms.

However, several sources in literature refer to the direct harming impact of the radiation. Almost all microorganisms are killed at a frequency of 2.450 MHz and a wavelength of 12,24 cm [55].

Technology

Different plants for different throughput capacities exist on the market. Most plants feature integrated shredder. A charging device processes the infectious waste into shredder. Subsequently, the shredded waste is moistened if necessary and treated with microwaves for 20 to 25 minutes in the disinfection chamber that is equipped with several microwave generators. After the treatment, the disinfected waste is filled into bags and can be combusted or processed to a sanitary landfill.

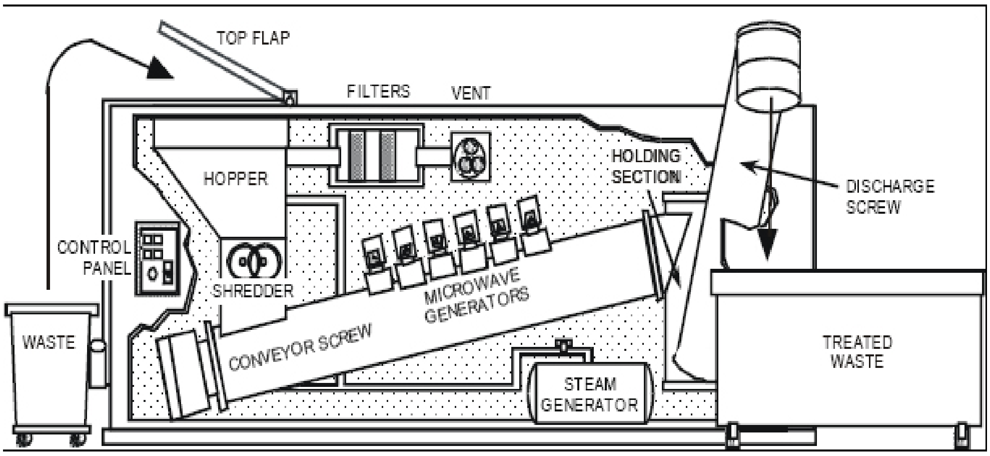

Abb. 31 Microwave treatment plant

In the majority of cases the operation of a microwave treatment plant is carried out as follows [56]:

- Waste collection: Waste collection in specially marked steam-permeable plastic bags to prevent the waste from adhering to the bags inner surface.
- Preparation, feeding: High-temperature steam is processed to the feeding hopper. During waste feeding air is evacuated from the treatment chamber.
- Internal comminution: After the mouth flap has been closed, the waste is processed to an internal shredder.
- Microwave treatment: After controlled crushing and with steam supply, the waste is processed to the treatment chamber by means of a screw conveyor. Inside the treatment chamber 4 to 6 microwave generators heat the waste to 95 to 100 °C. This state is maintained for at least 30 minutes.
- Second internal comminution (optional): The disinfected waste can be shredded again in a second shredder. It is especially suggested when treating sharp and spiky objects.
- Discharge: Discharge of the treatment chamber by means of a screw conveyor.
- Mechanical treatment: Before disposing of at a landfill, the disinfected waste will usually be compacted.

Characterisation

Like steam disinfection, microwave treatment is only suitable for infectious wastes (contaminated with obligatory pathogen microorganisms). The process requires special water contents of the waste to be treated. The heavily accident-sensitive shredder can cause temporary plant breakdowns. Filters have to be applied to prevent aerosol and odour emissions.

An advantage of microwave treatment is that disinfection can be reached with relatively easy measures and without the need to use large-volume pressure chambers. However, it does not reach the same process safety as steam disinfection with its fractionated vacuum technology.

Tab 54 shows the typical characteristics of microwave treatment.

Tab 54 Characterisation of microwave treatment

Appropriate types of waste	Infectious waste, sharps
Inappropriate types of waste	Radioactive waste, pharmaceutical and chemical products, pathological waste, animal carcasses
Type of treatment	Microwaves, steam
Throughput	Up to 400 kg/h
Additional remarks	Well-trained staff necessary High investment costs and operation expenses Minor environmental pollution
Source: [56]	

Like all treatment technologies mentioned above, microwave irradiation has certain advantages and disadvantages. They are presented in following table.

Tab 55 Advantages and disadvantages of microwave irradiation

Advantages	Disadvantages
• as the microwave technology is well known, there is a high acceptance by hospital management and staff • they are available for different capacities • when operated correctly, emissions are very low • some processes don't generate wastewater • at large plants the whole process will be automated	• massive odour emissions might occur • every hard and large object might damage the shredder • if the waste contains chemicals, these are released – untreated – as exhaust gas, into wastewater or to landfill • relatively high investment costs and operation expenses
Source: [56]	

Operation and equipment standards

As with steam disinfection, a well-trained technician is required for necessary repairs and operation control, at least in larger facilities. Hence, only HCFs with sufficient financial power can consider microwave irradiation as a possible treatment technology.

The necessary radiation time, dependents on the type of construction, must be complied with. To guarantee the disinfection of the material, the tested operation conditions that are mentioned in the inspection certificate must be observed.

The microbiological inactivation efficacy of microwave treatment has to be checked when starting operation and in certain intervals. The proceeding is equivalent to that of steam disinfection plants (see section 1.7.4.1).

Costs

Microwave treatment plants with a throughput of approx. 35 kg/h cost around 45,000 US$ on the US market. Large plants with capacities of around 400 kg/h cost 600,000 US$ [8]. These plants are equipped with internal shredder and compactors. However, cheaper and smaller plants with a low throughput also exist.

Dependent on the throughput, investment costs for microwave treatment range from 120,000 to 200,000 US$/(Mg*d) [58].

1.7.5 Land disposal

In developing countries, many smaller facilities don't have the money or opportunities for an orderly treatment of infectious wastes. However, possibilities to dispose of their waste must be made available to these financially weak facilities that are often located in rural areas. Only this can prevent open dumps from creation.

Abb. 32 Open health-care waste dumping

Open dumps can have far-reaching negative consequences, especially considering the infection risk for humans and animals or the environmental pollution. Direct inhalation or skin contact with the waste poses significant infection risks. However, indirect infections via the food chain or potable water are also possible. Additionally, open and uncontrolled fires can appear at the dumpsite. Abb. 33 shows consequences for humans and the environment as well as possible ways of infection.

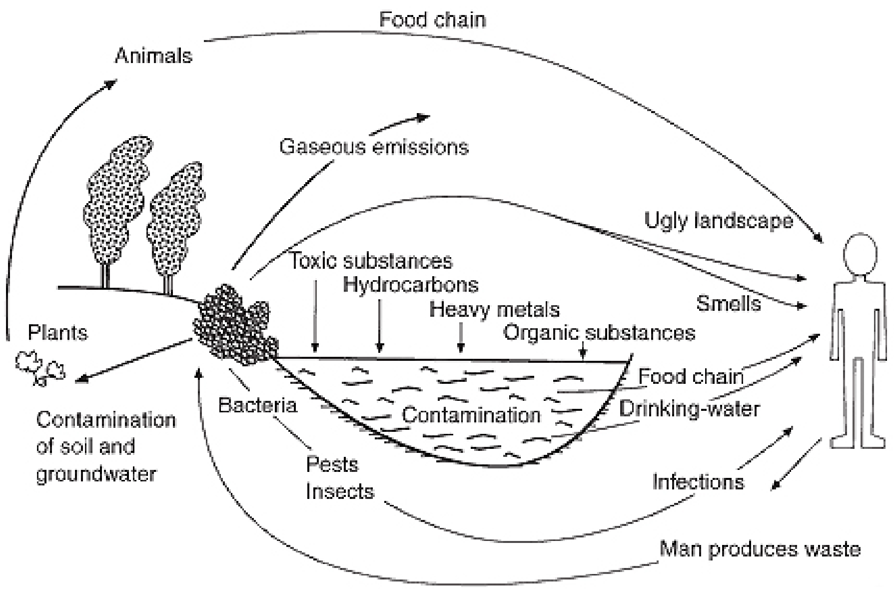

Abb. 33 Consequences and possible infection paths caused by open dumping

In developed countries, infectious waste can partially be disposed of to hazardous waste deposits with corresponding safety measures. However, this is hard to imagine for developing countries where appropriate landfills hardly exist and are difficult to realise.

1.7.5.1 Microbiological consequences of landfilling

Landfilling of microbiological critical waste leads to certain consequences for the pathogens contained in the waste.

After unloading the waste, aerobe conditions pre-dominate on landfills while temperatures in the landfill body begin to rise due to the beginning decomposition processes. Most aerobe bacteria and viruses are inactivated by this temperature rise. After the waste is covered, conditions change to anaerobe. Temperature rises to 60 °C. As most pathogen microorganisms prefer aerobe conditions and need temperatures around 28 to 45 °C to reproduce, they cannot spawn under the prevailing conditions and will partly die (note: viruses cannot reproduce outside of living cells). At a temperature of 60 °C, viruses, bacteria that don’t generate spores and pathogen fungi will die after approx. one hour.

Depending on the waste composition, the pH can reach extreme values (pH 1-3 or 9-14). Outside of a pH range from 6.0 to 8.0 most pathogen microorganisms are not able to reproduce or survive. [61]

Extensive examinations regarding the consequences of landfilling for the microorganisms were carried out at a model landfill were HCW and household wastes were landfilled at a ratio of 1:10 (quoted in: [61]). As a result, the number of aerobe bacteria massively decreased during the first six weeks. The indicator bacteria (*Coliform Bacilli*) could not be traced in the waste after 23 weeks. However, some microorganisms were found in the leachate.

In 1973, another experiment was carried out in the USA [61]. *Salmonella* bacteria and polioviruses were injected into samples, put onto a landfill and covered with solid waste and soil. Subsequently, the cover was compacted. The finding was that both species were no longer active after less than 10 days. Likewise, these microorganisms could not be traced in regions neighbouring the contaminated samples.

The mentioned studies show that most obligatory and optional pathogen germs are killed if landfilled according to ordinary regulations. Nevertheless, only small amounts of lightly contaminated waste should be co-landfilled with household waste. Additionally, every human (or animal) contact with the microbiological critical wastes must strictly be avoided. However, this cannot permanently be guaranteed in developing countries.

1.7.5.2 Waste pit with seal plate or lime covered

The construction of a deep waste pit with seal plate, similar to pits excavated for latrines, is a reasonable and cheap alternative to off-site landfills. To avoid long waste transports, this pit should be located on the terrain of the facility. All infectious or even pathologic wastes can be disposed of into the pit. To secure a long use, the infectious waste must be separated very exactly from the rest of the waste. Abb. 35 shows the design of a standard rectangular concrete septic vault.

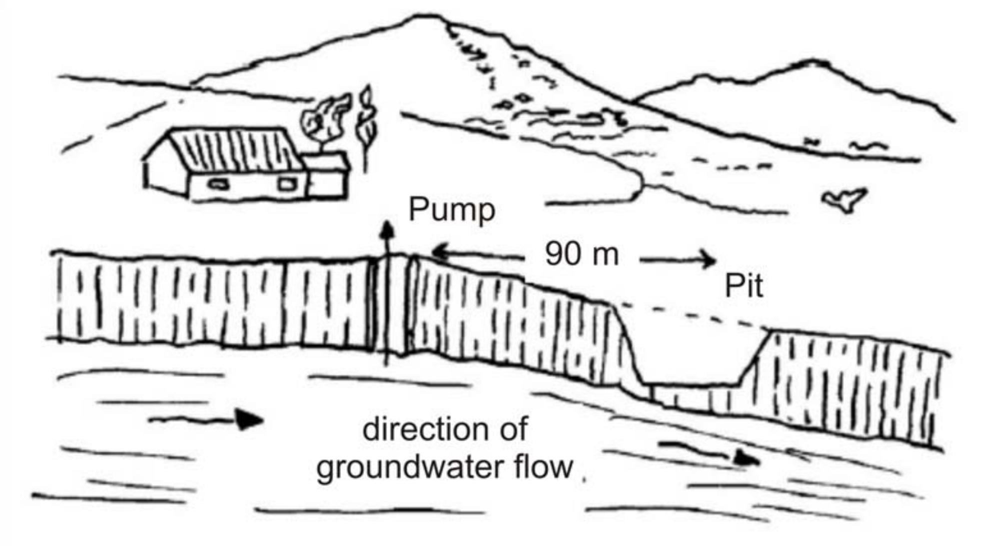

Abb. 34 Groundwater flow as criterion for pit position

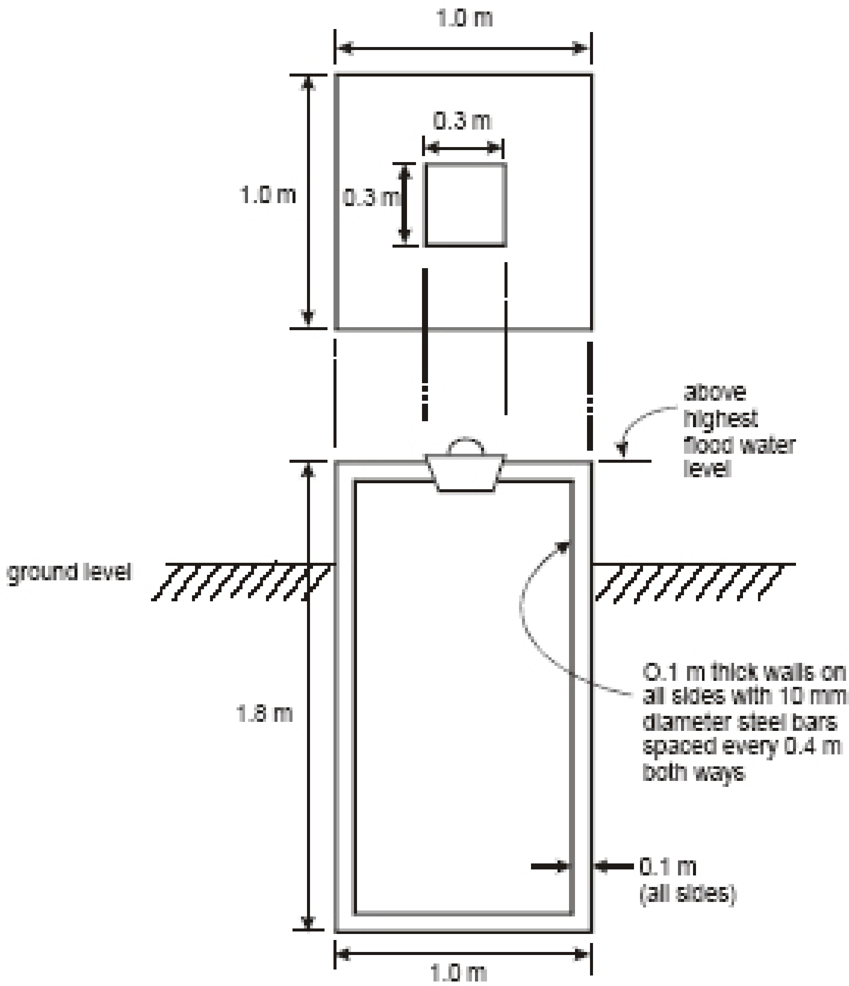

Abb. 35 Concrete septic vault design

A similar process is the covering of waste with lime. Shortly after disposal, the waste is covered with 10 to 15 cm layer of lime. If highly contagious infection diseases with obligate pathogen microorganisms occur, this cover layer should be enlarged and constructed of chlorinated lime. Abb. 36 shows an intersection of a small waste pit with lime.

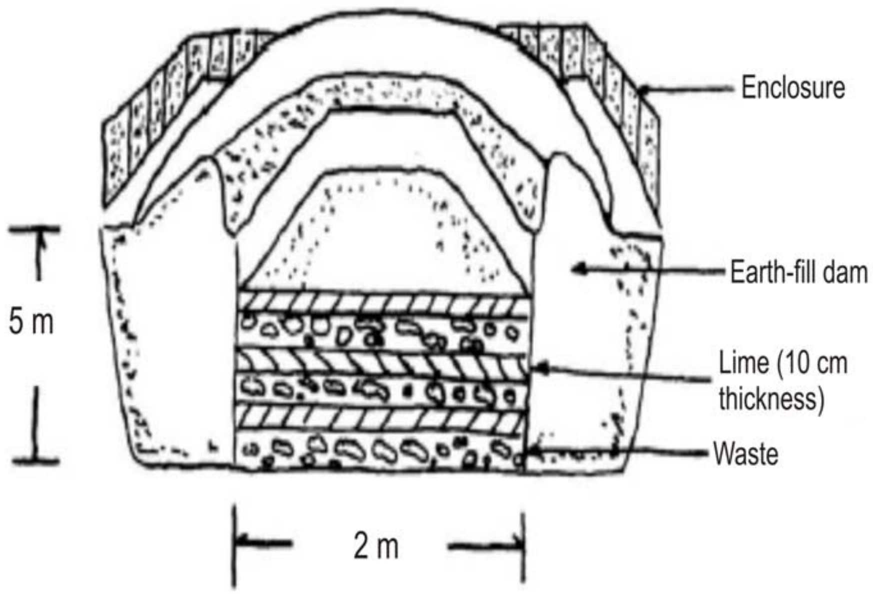

Abb. 36 Waste pit with lime cover

Access to these waste pits must be limited and should only be possible for instructed staff. When selecting the pit location and during waste disposal, the following steps should be adhered to:

- Selection of an appropriate location that is within a distance of, at most, 50 metres of any possible water spring to prevent water pollution. Additionally, the location should have drainage, be located downriver of existing springs and neither be situated on agricultural used area nor in a flood plain. The bottom of the pit should be about 1.5 meters above the groundwater level.
- Excavation of a pit, 1 to 2 metres wide and 2 to 5 metres deep. The distance between bottom of the pit and groundwater table should be at least 1.8 metres. For this purpose, local engineers or authorities have to be consulted.
- Fencing of the area, to hold off animals, waste picker and children.
- Covering of the waste. Newly delivered waste should instantly be covered with a soil layer, 10 to 30 centimetres thick.
- Sealing of the pit. Filling in of soil and sealing with concrete, when the pit is filled by two-thirds.

1.7.6 Evaluation and comparison

While selecting a treatment process for health-care wastes local circumstances and conditions should be taken into account. The planning engineer should consider the following factors:

- efficacy of the disinfection method,
- health and environmental impacts,
- reduction of volume and mass,
- industrial safety measures,
- operation and maintenance requirements,
- quantity of the waste to be treated and disposed of,
- throughput of the method,
- type of the waste to be treated and disposed of,
- infrastructural requirements,
- staff training requirements,
- available treatment options and technologies,
- disposal possibilities,
- existing area or space,
- location and surroundings of the treatment and disposal site,
- investment and operation costs,
- public acceptance and legal requirements [55].

It should be considered, that some landfill operators demand higher fees to dispose of disinfected (steam-treated) but still recognisable HCW.

To arrive at a suitable treatment or disposal method all specified criteria for choice must be considered. In developing countries the resulting costs represents the weightiest criterion for choice.

1.7.6.1 Disinfection safety

The treatment in sophisticated plants ensures in principle a high disinfection safety.

The highest disinfection safety ensures the incineration with high temperatures (> 1000 °C) in pyrolytic incinerators or rotary kilns. Small manual operated incinerators often don’t ensure the necessary temperatures to inactivate all infectious agents. Hence, this treatment option should only be used by small and financially weak HCFs or if an epidemic breaks out, if a off-site treatment isn’t advisable due to out of scale transport time.

Long experiences argue for treatment with steam. The microwave irradiation effectuates equivalent inactivation efficacy. This treatment option is successfully used in many HCFs in developed countries. Both treatment technologies reduce the number of obligate pathogen agents by more than 99,99%, if operation is accordingly.

The disposal in burial pits is the worst variety to manage infectious waste. This method is only allowed if funds to treat the infectious waste are not available.

1.7.6.2 Operation equipment required

The operation equipment required can limit the possible treatment options, especially for rural HCFs in developing countries.

Small incinerators require hardly additional operation equipment. Rotary kilns and pyrolytic incinerators require at least a bus bar. A certain amount of water is necessary to cool down ash where required.

Steam disinfection and microwave irradiation plants need a bus bar and a water connexion. Some plants don't have an own steam generator and utilise steam supply at hand in many HCFs. Only the small solar-powered disinfection plants don't need a bus bar but poor amount of water.

The following table exemplifies connexion and consumption values of a steam disinfection plant connected with steam generator with a throughput of circa 30 kg/h.

Tab 56 Connection and consumption values of a steam disinfection plant

Characteristic	Attribute
General information	
Maximum operating temperature	141°C
Maximum operating overpressure	2,8 bar
Dimension of usable space (h x w x d)	700 x 650 x 990 mm
Usable space without loading device	0,45 m^3
Connected values (electricity)	
Nominal voltage	230 / 400 volts (rotary current)
Nominal current	7 A
Nominal power	3 kW
Type of current	3/N/PE AC 400 volts
Nominal frequency	50 Hz
Connected values (water)	
Demineralised cold water	ca. 0,25 m^3/h
Softened water (< 1.78 ppm (mg $CaCo_3$/l))	ca. 1,2 m^3/h
Cold water	ca. 1,5 m^3/h
Consumption values (water)	
Demineralised cold water	ca. 0,024 m^3/h
Softened water (< 1.78 ppm (mg $CaCo_3$/l))	ca. 0,27 m^3/h
Cold water	ca. 0,32 m^3/h

Consumption values (electricity)	
Motor and control circuit (disinfection unit)	ca. 1,6 kW/h
Motor and control circuit (disinfection unit)	ca. 0,15 kW/h
Heating circuit	ca. 17,5 kW/h
Source: [62]	

1.7.6.3 Environmental impacts

The low temperature incineration in single chamber incinerators often causes formation of dioxins and furans. Poor combustion qualities give rise to extensive discharge of flue ash and soot. The incineration of HCW in high temperature incinerators (>800 °C) limits the formation of emissions [63]. However, temperatures may not be uniform and dioxins and furans can form in cooler pockets or during start-up or shut-down periods.

The water which accrues process-determined by steam disinfection needs a subsequent treatment. Microwave irradiation plants don’t always need a steam allowance, if the waste contains adequate moisture content before treatment. Hence, the waste water amount which must be treated may accrue in smidgen. The gaseous emissions are marginal versus incineration, because the main energy source is electricity.

Direct landfilling of infectious HCW in on-site pits cause significant environmental impacts. There is a high risk of groundwater and soil contamination, even if the pit is accordingly constructed.

1.7.6.4 Personnel requirements

The different technologies make different personal requirements. Some of HCFs have a lack of well-trained staff which is capable to operate the treatment plants. Training and educational measures are often not in progress due to the high expenses. Thus the personnel requirements and personal education may be an important selection criterion.

The combustion in small single chamber incinerators and the direct landfilling of infectious HCW in on-site waste pits require only low-skilled staff due to the simple operation.

Sophisticated plants with high treatment capacities require permanent operating surveillance and repair attendance by specially trained technician. For that reason, incinerators, steam disinfection and microwave irradiation plants with high throughput capacities are in the majority of cases operating off-site.

1.7.6.5 Costs

The resulting waste management costs incurred for HCFs can be differentiated between external and internal costs. Costs of separate collection, of necessary collection bins and of on-site treatment are internal costs. External costs can result from off-site transport, from the final disposal or from off-site treatment.

The costs of supply, interest, amortisation, operation and maintenance of treatment plants can be a substantial part of the overall budget. Hence, they should be considered as a constant. The arising costs are the sum of:

- investment costs (including site preparation and installation),
- costs of operation and maintenance (including costs of manpower and regulatory testing),
- interest and amortisation,
- costs of equipment (e.g. water and electricity)
- taxes, fees and other expenditures.

Investment costs are nonrecurring. The total costs of operation are dependent on the operating time and the costs of equipment needed and vary widely in different countries. The following tables show investment and capital costs of several treatment plants with a high throughput. In addition to the throughput, investment (capital) costs are heavily dependent on the required technical equipment.

Capital costs include all direct and indirect costs related to sitting and installation as well as the equipment purchase cost. Some treatment technologies require little site preparation and installation, while others involve significant installation requirements. Direct costs are (examples):

- site preparation,
- building (new construction or renovation),
- foundation and supports,
- electrical service,
- piping including steam and water lines,
- heating and ventilation system,
- air compressor,
- lighting,
- sanitary sewer,
- sprinkler system,
- painting and insulation,
- handling and on-site fabrication,
- equipment purchase cost (including auxiliary devices, instrumentation, carts for transporting waste, monitoring equipment, etc.) [56].

Examples of indirect costs that should be considered:

- project management,
- engineering,
- construction fees,
- regulatory inactivation testing,
- professional fees (including media fees to respond to public outcry, if the community does not like the technology choice)
- performance testing
- contingencies [56].

Tab 57 Capital costs of steam disinfection plants (US contractors)

Max. throughput	Procedure and equipment	Temperature	Costs (US$)
11 kg/h	Pre-vacuum – steam exposure – compaction (can also be used separately), automatic process control	132 °C	26.000
1017 kg/h			> 500.000
45 kg/cycle	Pre- and post vacuum, automatic process control	135-150°C;	90.000
680 kg/cycle			175.000

136 kg/h	Rotating autoclave, Pre- and post vacuum, controlled cooling-down and drying of treated waste, incl. post treatment grinder	145°C	382.000
250 kg/h	Pre-evacuation - steaming - compaction, automatic process control	140°C	286.000
680 kg/cycle	Pre- and post vacuum, automatic process control	135-150°C	175.000
Source: [56]			

Tab 58 Capital costs of microwave plants

Max. throughput	**Equipment**	**Temperature**	**Costs (US$)**
35 kg/h	Small mobile treatment plant, also applicable for intern use, Shredder and compactor optional	121-134°C	45.000
180 kg/h	Previous crushing, emptying by screw	95-100°C	500.000
400 kg/h	Previous crushing, emptying by screw	95-100°C	600.000
Source: [56]			

Tab 59 Investment costs of incinerators, southern Asia

Max. throughput	**Equipment**	**Costs (US$)**
50 kg/d	Manual loading and de-ashing, one combustion chamber, without flue-gas cleaning	20.000
100 kg/d	Manual loading and de-ashing, second combustion chamber (>1000°C), without flue-gas cleaning	200.000
100 kg/h	Manual loading and de-ashing, second combustion chamber (>1000°C), with flue-gas cleaning	400.000
200 kg/h	Automatic loading, manual de-ashing, second combustion chamber (>1000°C), with flue-gas cleaning	800.000
400 kg/h	Automatic loading and de-ashing, second combustion chamber (>1000°C), with flue-gas cleaning	1.700.000
Source: [55]		

The previous tables show that a conversion in arising treatment costs per (metric) tonne of waste to be treated doesn't make sense. Thus the several technologies would be comparable with one another, but the value is over dependent on territorial differential operation costs, the required equipment and the quantity of waste to be treated. A reasonable approach is the comparison of capital costs for every technology relating to maximum throughput, like represented in Tab 60.

Tab 60 Estimated range of investment costs per ton of treatment throughput

Technology	Approximate investment cost (US$/ton/day)
Microwave irradiation	120.000 – 200.000
Steam disinfection	40.000 – 125.000
Incineration (with flue gas cleaning)	120.000 – 400.000
Incineration (without flue gas cleaning)	10.000 – 100.000
Sources: [55], [56], [58]	

Annual costs are costs incurred every year, unlike investment costs. Costs which are dependent on the throughput of the plant are direct costs, e.g.:

- labour (operating and supervisory);
- utilities:
    - electricity,
    - steam,
    - natural gas,
    - water,
    - compressed air;
- supplies:
    - boxes or containers,
    - autoclavable or steam permeable bags,
    - labels;
- maintenance (scheduled and unscheduled);
- materials;
- maintenance labour;
- landfill disposal costs (including transportation and tipping fees);
- cost of treating waste during scheduled and unscheduled downtime [56].
- Steam permeable bags necessary for steam disinfection cost in the USA circa 18 US$ per 100 pieces [56]. The price on the European market ranges to 2,50 € per piece.

Indirect costs are costs that are not proportional to throughput and are heavily dependent on regional circumstances, such as:

- overhead,
- administrative costs,
- insurance,
- annual regulatory permit fees,
- periodic verification or emission tests,
- taxes [56].

1.7.6.6 Evaluation matrix

The above mentioned criteria are reflected in an evaluation matrix. This matrix may provide a basis to select an appropriate infectious waste treatment or disposal practice in consideration of specific circumstances

The properties in principle are evaluated and compared. However, individual applications can differ from evaluations indicated here.

The evaluation of the methods is generally carried out concerning suitability in developing countries. The evaluation matrix does not replace the knowledge of local conditions on no account.

Some criteria are additionally mentioned, e.g. the destruction of sharps. These can be helpfully to select an appropriate method.

Tab 61 Evaluation matrix of infectious waste treatment and disposal methods

<table>
<tr><td rowspan="2">Evaluation</td><td colspan="5">better ---></td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Criterion</td><td colspan="5">Method</td></tr>
<tr><td>Microbiological inactivation</td><td>On-site waste pit</td><td>Low temperature incineration</td><td>Microwave irradiation</td><td>Steam disinfection</td><td>High temperature incineration</td></tr>
<tr><td>Destruction of sharps</td><td>On-site waste pit</td><td>Low temperature incineration</td><td colspan="2">Microwave irradiation
Steam disinfection
(if waste is shredded)</td><td>High temperature incineration</td></tr>
<tr><td>Destruction of body parts</td><td>On-site waste pit</td><td colspan="2">Microwave irradiation
Steam disinfection</td><td>Low temperature incineration</td><td>High temperature incineration</td></tr>
<tr><td>Prevention of environmental impacts</td><td>On-site waste pit</td><td>Low temperature incineration</td><td>Steam disinfection</td><td>High temperature incineration
(with flue gas cleaning)</td><td>Microwave irradiation</td></tr>
<tr><td>Prevention of direct human contact</td><td>On-site waste pit</td><td>Low temperature incineration</td><td colspan="3">Steam disinfection
Microwave irradiation
High temperature incineration</td></tr>
</table>

Requirement of additional equipment	Steam disinfection High temperature incineration		Microwave irradiation	Low temperature incineration	On-site waste pit
Personnel requirements	Steam disinfection Microwave irradiation		High temperature incineration	Low temperature incineration	On-site waste pit
Costs	Microwave irradiation	High temperature incineration (with flue gas cleaning)	Steam disinfection	Low temperature incineration	On-site waste pit

1.8 Treatment and disposal options for other waste categories

Most of the above (section 2.7) described treatment and disposal technologies for infectious waste are not appropriate for other waste categories. In some cases, however, other waste categories, such as radioactive waste, incur and must be treated or disposed off under special requirements. Great quantities of sharps may be generated in rural areas while immunisation campaigns or epidemics. Then treatment plants are often not available and cost-saving and simple methods to treat or dispose this waste category are in demand.

1.8.1 Sharps

Proceeding from the assumption that sharps, like scalpels, cannulas, syringes, needles etc., from medical and laboratory work are contaminated with blood or substance from blood and body fluids, the risks of infection in danger of injuring is high. The handling for destroying infectious microorganisms by heat, by chemical means or by microwave irradiation should be at the earliest stage possible and is described above.

The treatment option for sharps should be chosen according to the national and local situation and should undergo incineration whenever possible (together with other infectious waste). After incineration or other disinfection, the residues may be disposal on a dumpsite. Adequate, the encapsulation is suitable for. [55]

If it is not possible to use any of the treatment options, the burning of sharps in open trenches may be envisaged. [55]

From a technology standpoint, safely treat and dispose of sharps on low-cost technologies with potential applications in developing country areas exist. Other the above mentioned options of treatment, the alternative technologies presented in this chapter are:

- cement encasing,
- encapsulation with immobilising agents,
- waste burial pit with concrete cover (similar to waste burial pit for infectious waste (section 1.7.5.2),
- point-of-use needle destruction technologies.

In addition, small portable steam treatment units with traditional grinders, according to the different systems described in chapter above, are in use.

1.8.1.1 Encasing and Encapsulation

Cement encasing is an option in areas where volume is not a primary concern. It is a connection of disinfection and final disposal. For a safe treatment, a careful in handling and transporting as like a workers training are needed. Furthermore the size of the trench (based on the amount of waste to be disposed for a specific period) needs to determine. Abb. 37 shows a cement encasing option.

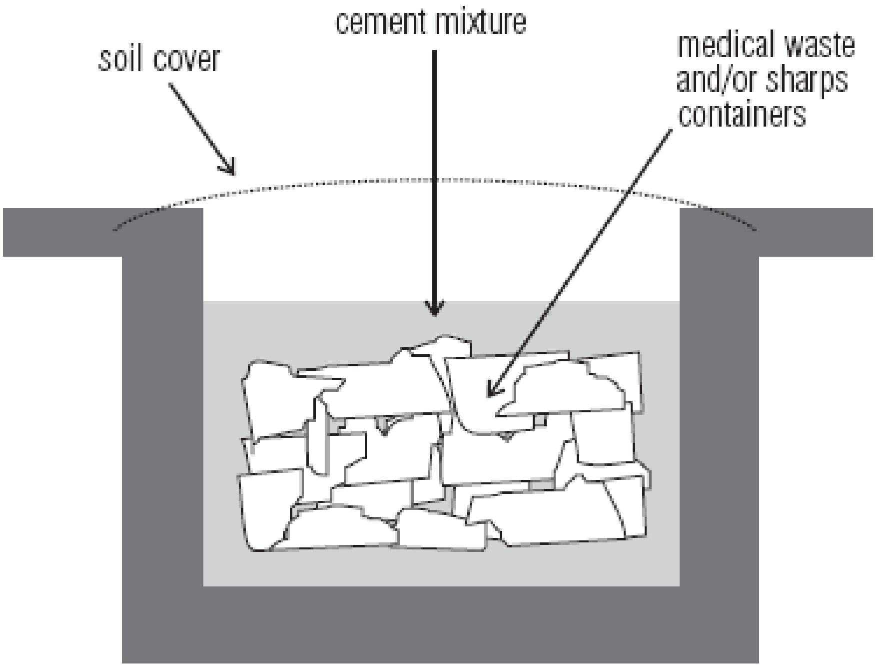

Abb. 37 Cement encasing

The method involves a complete cement mixture surrounding and a soil cover with about 15 cm on the top. For a cement mixture, to flow easily and fill up voids and empty spaces in the waste, it is advisable to a typical recipe for the cement mixture:

- 1 part cement
- 1 part lime
- 4 parts sand
- one-third to one-half part water [64].

A modification of this method is the construction of underground reinforced concrete casings or bunkers. A different method involves placing the sharps waste in hard containers such as metal drums (up to three-quarters full), showed in Abb. 38, and adding an immobilising material (like bituminous sand, clay, or cement mortar). The container is then sealed and ready to transport to the local landfill for example. [64]

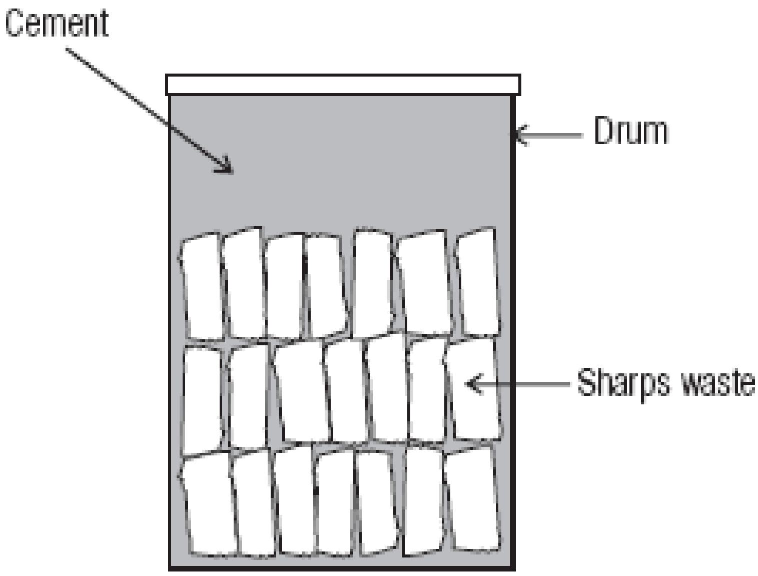

Abb. 38 Encapsulation with immobilising materials

As clue to rate the necessary quantity of cement and costs needed, the following table provides an estimate of the trench volume and cement needed for disposing of the sharps waste from pentavalent vaccine immunisation (DTP-HepBHib) which requires three doses per child in the case of immunisation waste.

Tab 62 Estimated trench volume and cement needed for DTP-HepBHib vaccination waste, Source: [2]

Number of children targeted for vaccination	**100**	**1000**	**5000**	**10000**
Number of safety boxes	8	75	377	753
Volume of sharps waste [m³]	0,04	0,042	2,12	4,25
Trench volume [m³]	0,08	0,85	4,25	8,49
Amount of cement needed [kg]	10	96	478	955

Approximate cost of cement, lime, and sand [US $]	5	43	215	430
Source: [64]				

1.8.1.2 Burial pit with concrete cover

Abb. 39 shows the basic design for a sharps waste burial pit. The requirements on positioning and design of the burial pit are the same like mentioned in section 2.7.5.2. The bottom of the pit should be about 1.5 meters above the groundwater level. In the course of use the main reason of the flexible cement or concrete cover is to prevent scavenging. In the end a final 50 cm layer of soil should cover the burial pit. The soil underneath the liner of a geomembrane should be smooth to prevent punctures. Between the liner and sharps containers should be a 25 cm layer of soil. A pit with the dimensions 1 m x 1 m x 2 m can accommodate around 200 5-liter safety boxes or about 20.000 used needles and syringes [64].

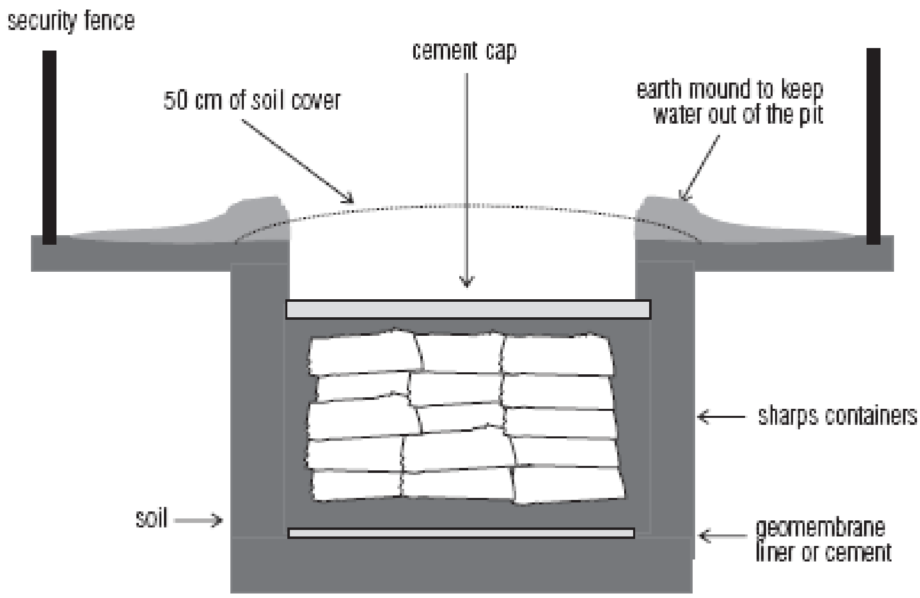

Abb. 39 Sharps waste burial pit

In areas where safety boxes or standard sharps containers are not available, sharps can be collected safely in hard plastic bleach containers where the sharps waste can be left soaking in a 0.5% chlorine bleach disinfectant solution as an alternative. The containers can then be placed in a waste burial pit and covered with soil, concrete, and a top-soil cover.

1.8.1.3 Point-of-Use Needle Destruction Technologies

One way of helping to reduce the risk of needle-sticks is by using sharps waste treatment technologies near the point of use. There are principally four types of point-of-use needle destruction technologies available:

- Mechanical needle cutters,
- Motorised cutters,
- Electrical spark devices, and
- Encapsulating systems [64].

These technologies may be useful in particular situations and are options to complement other treatment approaches.

Different manual systems to cut off needles or needle tips from syringes are used for mechanical needle cutters, where no electricity is needed for these devices. The aim is to shear the nib from the syringe and cut the needles into several pieces. Similar to the mechanical cutters but used by an electrical motor to cut off and chop up the needle portions are motorised cutters. They are able to handle a wider range of needle sizes and the needle portions can be disinfected and/or encapsulated prior to burial with mechanical systems.

Internal electrodes which produce an electrical spark to melt and burn off the ends of the needle for a few seconds at very high temperatures are used in electric spark systems. They range from plug-in desktop units to battery-run portable devices. [64]

The wastes from sharps encased in a hardened material are the effect of encapsulation systems to dispose the wastes as regular garbage. [64]

1.8.2 Pharmaceutical waste

Disposal of small amounts of solid or liquid pharmaceutical waste is easy and relatively cheap in relation to large amounts, which require special treatment facilities.

1.8.2.1 Small quantities

The disposal options for small quantities of pharmaceutical waste include:

- landfill disposal,
- encapsulation,
- safe burial on hospital premises,
- discharge to a sewer,
- incineration.

This chapter will be given an overview to those outlines.

Landfill disposal:

Pharmaceutical waste in small quantity produced on a daily basis may be landfilled in mixture with a large quantity of general municipal solid waste. Landfill means to place the waste directly into a land disposal site without prior treatment or preparation. Properly constructed and operated landfill sites, like highly engineered sanitary landfills, offer a relatively safe disposal route for municipal solid wastes, including waste pharmaceuticals. The top priority is protection of the aquifer. Cytotoxic and narcotic drugs, even in small quantities, should never be landfilled. These compounds needed a special treatment (see section below). [55], [65]

Encapsulation:

Small quantities of pharmaceutical waste, together with sharps if appropriate, may be encapsulated. The encapsulation, described in chapter 2.8.1.1 above, involves immobilising the pharmaceuticals in a solid block within a plastic or steel drum. The drums are filled to 75% capacity with pharmaceuticals, and the remaining space is filled by pouring in an immobilising material (such as cement or cement/lime mixture, plastic foam or bituminous sand). As soon as the drums are filled to a 75% capacity, a typical recipe for the mixture of lime, cement and water in the proportions 15:15:5 (by weight) should be added so that the drum filled to 100% capacity. In case of a non liquid consistency, a larger quantity of water may be required to attain a satisfactory. Further the sealed drums should be placed at the base of a landfill and covered with fresh municipal solid waste after. [55], [65]

Safe burial on hospital premises:

The safe burial of small quantities of pharmaceutical waste prevents scavenging and may be an appropriate disposal method for establishments applying minimal programmes. [55]

Discharge to a sewer:

Liquid pharmaceuticals can be diluted with water and flushed into the sewers in small quantities over a period of time. This effect in a large flow of water should be under control without serious public health or environmental affect. For slow-moving or stagnant water bodies is this procedure not acceptable, even not for small quantity. [65]

Incineration:

Burning pharmaceutical waste is not advocated as a method of disposal and should not be destroyed at low temperature, as toxic pollutants may be released into the air. It is recommended that only very small quantities of waste pharmaceuticals be disposed of in this way and may be incinerated together with infectious or general waste, provided that they do not form more than 1% of the total waste. [55], [65]

1.8.2.2 Large quantities

In case of emergencies or a pharmacy closes down may have to be dealt with large quantities of pharmaceutical waste.

The treatment methods for large quantities of pharmaceutical waste include:

- Incineration at high temperatures, and
- Encapsulation.

Incineration:

Incineration is the best method to dispose pharmaceutical waste. The pharmaceutical wastes should be mixed with other combustible material (such as cardboard packaging or general waste), to ensure optimal combustion conditions. In an ideal way they should be treated in incinerators designed for industrial waste, which can operate at high temperatures over 1200°C. The pharmaceutical waste is also accepted as an alternative fuel to produce cement in cement kilns, with no more than 5% of the fuel fed into the furnace. The low-temperature incineration, lower than 800°C, provides only limited treatment for this type of waste, because off potentially toxic exhaust gases that may be produced. In this case the pharmaceutical waste should be diluted with a ratio of approximately 1:1000 with municipal waste. [55], [65]

Note: Ampoules should be crushed on a hard, impermeable surface and not be incinerated as they may explode, damaging the incinerator or injuring workers.

Encapsulation:

If there are no incineration possibilities, pharmaceutical waste can also be encapsulated in drums (see section 1.8.1.1) and after deposited on a sanitary landfill site, where the risk of groundwater contamination is minimised.

Note: Landfilling of large quantities of pharmaceuticals is not recommended unless the waste is encapsulated. Neither should they diluted or discharged into sewers.

1.8.3 Cytotoxic waste

Cytotoxic waste must not be disposed into the sewerage system or be landfilled due to this waste is highly hazardous. Only the following options include disposal and treatment methods:

- return to supplier,
- incineration at high temperature,
- chemical degradation.

1.8.3.1 Return to original supplier

Outdated drugs and drugs that are no longer needed should be returned to the supplier in safe boxes and marked with “outdated” or “not for use”. For countries that lack the facilities for incineration, this is the favoured option at present.

1.8.3.2 Incineration at high temperatures

For the full destruction of all cytotoxic substances may require temperatures up to 1200°C to destroy common cytotoxic products, otherwise hazardous cytotoxic may vapours into the atmosphere. Modern incinerators, fitted with gas-cleaning equipment, are suitable to provided, that a temperature of 1200°C with a minimum gas residence time of 2 seconds or 1000°C with a minimum gas residence time of 5 seconds can be achieved. The cytotoxic waste incineration is also possible in rotary kilns, designed for thermal decomposition of chemical wastes, with more than 850°C in the furnace. The disposal of cytotoxic waste in municipal incinerators, in single-chamber incinerators, or by open-air burning is inappropriate. [55]

1.8.3.3 Chemical degradation

One option to inactivate cytotoxic substances is the chemical degradation. The results are non-toxic/non-genotoxic compounds. This method can be used not only for drug residues but also for cleaning and protecting of materials and be appropriated for developing countries.

The existing restriction is that this method is only appropriate to some categories of substances. The chemical degradation effects the neutralisation or decomposition of substances by addition of sodium hydroxide solutions or similar substances. The main disadvantage is that the sewage load will increase due to the inactivation-reagents are added in surplus. [66]

Tab 63 gives chemical degradation methods for selected cytostatic compounds. Tab 64 provides other cytostatic drugs for which chemical degradation methods are available.

Tab 63 Chemical degradation methods for selected cytostatic compounds

INN (Trade Name Producer)	Deactivation Method
Actinomycin D	Small quantities: spike with 5 percent solution of Trisodiumphosphate in period of 15 minutes.
Bleomycin	Dilute down to circa 1 percent solution, addition of 1 g caustic soda / 100 ml. After 5 hours neutralise with acetic or hydrochloric acid.
Cisplatin	Treat with diluted hydrochloric acid in the presence of aluminium. (e.g. roll crimp of injection bottle). The substance will be reduce till metallic platinum.
Cyclophosphamid	Treatment with circa 0,2 N methanolic caustic potash solution (circa 1 hour at room temperature)
Cytarabin	Dilute down to circa 1 per cent solution, additon of 4 caustic soda / 100 ml. Addition of 10 ml 30 persent hydrogen peroxide after cooling-down, then boil 45 min. on the reflux condenser. After cool down neutralise with acetic or hydrochloric acid.

Daunorubicin	Treat with chlorine bleaching solution (sodium hypochlorite solution), which is diluted 1 to 10 relative to water. The active ingredient molecule oxidation is indicate by decolouration .
Doxorubicin	Like by Daunorubicin
Extramustin	Treat with 5-10 percent methane caustic soda (24 hours) at room temperature.
5-Fluorouracil	Treat with concentrated NaOH in period of several hours Proceed like by Daunorubicin
Methotrexat	Treat with 1 N-NaOH or NH_4OH-solution. Optimal practice would be an autoclaving in period of 1 hour at 121 °C/ 200 000 pascal.
Mitomycin	Treatment with strong acids. Decomposition by Mitomycin at ph < 1.
Mitoxandrone	Per gram Mitoxandron-HCl addition of 20g circa 40 percent calcium hypochlorite solution (flue!).
Thiotepa	Dissolve in water and add slowly 5 percent hydrochloric acid by possibly cool down. Abandon for 1 hour at least.
Source: [66]	

Note: These methods are not appropriate for the treatment of contaminated body fluids. For countries where neither high-temperature incineration nor chemical degradation methods are available and the exportation to a place with an adequate treatment for the cytotoxic waste is not possible, encapsulation or inertization may be considered as a last resort.

Tab 64 Cytotoxic drugs for which chemical degradation methods exist

Carmustine	Doxorubicin	Semustine
Chlorambucil	Ifosfamide	Spiromustine
Chlormethine	Lomustine	Streptozocin
Chlorozotocin	Melphalan	6-Thioguanine
Cisplatin	6-Mercaptopurine	Uramustine
Cyclophosphamide	Methotrexate	Vincristine sulfate
Daunorubicin	PCNU*	Vinblastine sulfate
Dichloromethotrexate	Procarbazine	
Source: [55], *1-(2-Chloroethyl)-3-(2,6-dioxo-3-piperidyl)-1-nitrosourea		

Antineoplastic drugs have the ability to kill or stop growth of living cells. They are used in the chemotherapy in specialised treatment centres. Their disposal must therefore be handled with care, if they are unwanted and discharged into the environment. Antineoplastics should be segregated from other pharmaceuticals and kept separately in clearly marked containers, be safely packaged with rigid walls and returned to the supplier for disposal. If this option is not possible they must be destroyed by incineration which operates at a high temperature of at least 1200°C. [65]

For encapsulation the antineoplastics drums should be filled to 50% capacity with drugs, after which a mixture of lime, cement and water in the proportions of 15:15:5 (by weight), should be added and the drums filled to 100% capacity. [65]

Note: Antineoplastic drugs/waste should never be disposed of in a landfill, other than after encapsulation or inertization.

1.8.4 Chemical waste

1.8.4.1 General chemical waste

For non-recyclable, non-hazardous only general chemical waste (such as sugars, amino acids and certain salts), exist options like disposed of with municipal waste or discharged into sewers. The disposal of aqueous chemical non-hazardous wastes into sewers is traditional accepted by sewerage authorities in many countries. An official permission from the appropriate authority should require the types, limit and quantities of the chemical compound that can be discharged. An official permission should described the conditions for discharge and may include restrictions on pollutant concentrations, content of suspended solids, temperature, pH, and the rate of discharge. Otherwise an unauthorized discharge of hazardous chemicals may adversely affect the functioning of sewage treatment works and can be dangerous to sewage treatment workers. For this reason chemical waste, such as petroleum spirit, calcium carbide, and halogenated organic solvents, should not be discharged into sewers. Therefore exist dependent on the amount of quantity of hazardous chemical waste different disposal options. [55]

Note: Non-pharmaceutical, potentially dangerous waste such as chemicals must be dealt with a case-by-case basis, a separate and careful labelling on the drum and storage until disposal by a hazardous waste expert. [55]

1.8.4.2 Small quantities of hazardous chemical waste

For small quantities, e.g. residues of chemicals inside their packaging, may be dealt with by incineration, encapsulation, or landfilling as described for pharmaceutical waste above.

Note: Pure and clear acids, alkalis, reagents, phenol-based chemicals used for cleaning floors, disinfectants, etc. can be put to good use again.

1.8.4.3 Large quantities of hazardous chemical waste

Different from this is no way to dispose (both: safe and cheap) of large and significant quantities of hazardous chemical waste. In case of certain combustible wastes including many solvents, the waste mixture should be incinerated with high temperature and gas-cleaning equipment (containing chlorine or fluorine for instance). Companies or organisations specialised and authorised to manage hazardous waste handle and disposal chemical wastes that cannot be safely and efficiently incinerated. This companies or organisations may eliminate the wastes in a rotary kiln, treat them chemically, or store them in a safe disposal facility engineered for hazardous chemicals. Other possibilities for disposing are returning the hazardous chemicals to the original supplier or chemical waste could also be exported to a country with safe expertise and facilities. Shipments comply with international agreements such as the Basle Convention should be used for this purpose. [55]

The following additional measurements should also principal recommended for security reasons:

- To avoid unwanted chemical reactions, the hazardous chemical wastes of different composition should be stored separately.
- Chemical waste in large amounts should not be buried to prevent contaminate water sources.
- Chemical disinfectants in large amounts should never be encapsulated, because they are corrosive and sometimes flammable. [55]

Note: Landfilling of large quantities of chemical waste is not recommended.

1.8.5 Waste with high heavy-metal content

Waste containing or contaminations with heavy metals (such as mercury, nickel or cadmium) should never be burned or incinerated. The emissions pollute the atmospheric with toxic vapours. Furthermore they should never be disposed of in municipal landfills because of the risk of groundwater pollution. Industries specialising in the recovery of heavy metals, mercury- and/or cadmium-containing, waste can be sent to these facilities for recycling/recovery of the valuable materials – this should be the best solution. With a view to reprocessing, recycling or final disposal, it should also be possible to send back the waste to the suppliers of the original equipment in safe boxes and marked, but this might be unusual for the suppliers, because they are reluctant to accept these wastes. The heavy metal waste could also be exported to a country with safe expertise and facilities should also be considered for its adequate treatment. [55]

If none of the above options is feasible a minimal programme of prevention for treatment should be established. Encapsulation followed by disposal in an impermeable landfill (if available), the wastes may be disposed of in a safe storage site especially designed for the final disposal of hazardous industrial waste. In case the heavy-metal content is minimal, in similar quantities to the present municipal wastes, and there are no facilities for recovery of heavy metals within the country, this waste may join the municipal waste stream. [55]

1.8.6 Pressurised containers

With the risk of explosion, incineration or burning is not a disposal option for pressurised containers or aerosol cans. Preferential treatments are recycling and reuse, so that undamaged pressurised containers may be sent back to the gas suppliers for refilling. This contains appropriate arrangements for the return of containers in the original purchase contracts. In special situations, such as halogenated agents in liquid form, supplied in glass bottles, should be handled as hazardous chemical waste and disposed of as such.

The following undamaged containers:

- nitrous oxide cartridges or cylinders,
- ethylene oxide cartridges or cylinders,
- pressurised cylinders for other gases (such as oxygen, nitrogen, carbon dioxide, compressed air, cyclopropane, hydrogen, petroleum gases (for heating and cooking), and acetylene (for welding))

should be returned to the supplier. [55]

Before pressurised containers, that are unsuitable for refilling or have been damaged, can be disposed of in any landfill, they should be crushed after being complete empty. If the return of empty containers to the gas suppliers is uneconomical, this option may also be selected. Furthermore industry companies specialising in recovery of metals may also accept damaged pressurised containers. The only safe solution in extreme cases, where containers have corroded valves and still have residual pressure, is to assemble them at a safe location (e.g. a military training area) and arrange for qualified specialists to destroy them by controlled explosion. [55]

Aerosol cans in low quantities should be collected and disposed of with general waste in waste bags, but only if this waste is not intended for burning or incineration. Large quantities of disposable aerosol cans should be returned to the supplier or sent to recycling plants, where it is possible. [55]

1.8.7 Radioactive waste

The safe management, handling and disposal of radioactive waste require a national strategy and infrastructure, as soon as a rigorous and relatively complex management scheme. That includes:

- appropriate legislation,
- a competent regulatory organisation,
- radiation protection officer, and
- trained personnel.

To observe this strategy each hospital or laboratory that uses unsealed radioactive sources should designate a trained Radiation Officer who will be responsible for the safe use of radioactive substances, for record-keeping, for safe-keeping and waste management process. [55]

On the basis of the available options for treatment, conditioning, storage, and disposal the radioactive waste should be categorised and segregated with information like:

- half-life, short-lived,
- activity and radionuclide-content,
- physical and chemical form,
- sealed/non-sealed sources,
- waste content [55].

Each category of waste should be kept separately. Possible versions are special containers for liquid and solid waste. They should design with:

- clearly identification,
- bear a radiation trefoil symbol when in use,
- robust,
- compatible with the waste contents, and
- capable of being filled and emptied safely [55].

And the following information should be recorded for each waste container:

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

Each HCF or laboratory that uses unsealed radioactive sources for diagnostic, therapeutic, or research purposes have to be managed radioactive HCW. The management of radioactive HCW include the following methods or steps:

- exemption and clearance,
- recycling and reuse,
- return to supplier,
- storage,
- treatment and conditioning,
- discharge/disposal [55].

These are outlined in the following paragraphs.

1.8.7.1 Exemption and clearance

Radioactive wastes can be exempted, or released, from regulatory control, if they represent a negligible radiological hazard with a radioactivity below the clearance levels established by International Atomic Energy Agency, as describe above. The radioactive materials have to be monitored and recorded to demonstrate the compliance with the regulations. Low-level radioactive waste should be stored for decay to the clearance levels. [55]

Note: Exemption of radioactive HCW from regulatory control does not mean that it is also exempt from regulatory control of other hazards!

1.8.7.2 Recycling and reuse

The reuse and/or recycling of radioactive materials are part of the approval by the regulatory authority. Companies or organisations specialised and authorised to manage recycling and reuse of radioactive materials include:

- reuse of sealed sources,
- decontamination and reuse of equipment and protective clothing, and
- reuse of dilute waste streams. [55]

If circumstances permit, recycling and reuse should always be considered as an alternative to disposal. Special attention should be given for two main points. First to the implications of producing secondary waste streams and secondly to the need to ensure that sealed sources are in a serviceable condition and suitable for the intended application. [55]

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

1.8.7.3 Return to supplier

One aim for spent sealed sources is that those should be returned to suppliers, if it is possible at all. This is mainly important for sources with high activity and those containing long-lived radionuclides, which are used for therapeutic purposes. Such items in sealed sources, in the form of pills, seeds, ribbons, capsules or tubes, may become waste if their conditions are damaged, or the activity has decayed, or they are no longer required. Hospitals should send them back to the supplier for reprocessing, recycling, or safe disposal in their containers or other appropriate packages. [55]

1.8.7.4 Storage

Storage facilities should be designed to provide physical security and radiological protection for untreated, treated, and conditioned radioactive health-care waste. Special care is needed for the storage of unconditioned waste in order to limit the risk of dispersion. For that reason, areas for untreated waste should be separate from radioactive waste. Radioactive waste must be stored in such a way that human health and the environment are protected; without corrosive, explosive or flammable materials. All radioactive waste that is to be stored during decay should be kept in suitable containers that prevent dispersion of their content, can or drum should be used. These containers should be clearly marked with the words "RADIOACTIVE WASTE" and the radiation symbol. The containers should be stored in a specially designated area in storage rooms designed specially for radioactive substances or waste. [55]

Facilities or areas for radioactive waste or radioactive HCW must be clearly demarcated, with controlled access, and should have the characteristics showed in Tab 65.

Tab 65 Characteristics of storage facilities/areas for radioactive health-care waste

- sufficient capacities to accommodate all waste generated before discharge, treatment, or transportation,
- simple construction, with non-flammable walls and floors that may be easily decontaminated,
- impermeable floor covering, with a containment edge and slight slope to a central collection area,
- adequate ventilation,
- air sampling and radiation alarms (as required by the regulatory authority),
- fire detection/control equipment (as required by the regulatory authority),
- fire-resistant, lockable doors,
- compartments to allow separation of different kinds of waste (e.g. to facilitate the safe storage of materials presenting particular hazards),
- demarcation as radiologically controlled areas,
- a log-book, listing the number of containers, entry date, waste types, activity, etc., which should be kept outside, but near, the storage room or area,
- protection from the environment (weather), including extremes of temperature,
- protection against unauthorised entry and against the intrusion of animals, insects, etc.,
- movable radiation shielding (placed as appropriate to protect workers from radiation,.

1.8.7.5 Treatment and conditioning

Treatment and conditioning should be undertaken to improve the characteristics of waste before temporary storage and/or disposal. Treatment includes operations by changing the characteristics of the radioactive waste to improve safety or economy reasons. The basic objectives are shown in Tab 66.

Tab 66 Basic objectives for treatment to improve the characteristic of radioactive waste

	for solid waste	for liquid waste
Volume reduction	shredding, low-force compaction, controlled incineration	evaporation under controlled conditions
Removal of radionuclide	decontamination	ion exchange
Change of composition		Precipitation filtration
Source: [55]		

Those operations convert radioactive waste into a form that is more suitable for handling, transportation, storage, and disposal and may include immobilisation of radioactive waste in concrete, placing the waste in suitable containers, and providing additional packaging. In many instances, treatment and conditioning take place in close physical conjunction with one another. [55]

Note: Treatment processes also may result in the production of secondary radioactive waste streams (contaminated filters, spent resins, sludge, ash), which also need to be appropriately managed.

1.8.7.6 Discharge/disposal

The management may involve before disposal the concentration and containment of radioactive waste, and also the discharge of effluents into the environment. Health-care institutions should ensure that radionuclides are not released to the environment unless:

- the activity released is confirmed to be below the clearance levels; or
- the activity of the liquid or gaseous effluents discharged is within limits authorised by the regulatory authority. [55]

Health-care institutions wishing to release radioactive waste with activity above the clearance levels should apply for an authorisation with a management factor of safety. The final step in the management of radioactive waste is disposal. Basically, it involves the placement of radioactive waste in a disposal facility that provides reasonable assurance of safety. In general, there is no intention of retrieval, and no long-term surveillance or maintenance of the disposal site. A complex and costly undertaking is the organisation of an engineered disposal facility. Health-care institutions should submit its proposals for disposal to the regulatory authority, if radioactive waste is not suitable for discharge or release to the environment or for clearance within a reasonable time. [55]

Note: Radioactive wastes can not be destroyed, they can only disposal of in a landfill finally, and degrade without causing harm to humans and the environment.

Additional remarks:

- 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.
- Higher-level radioactive waste of relatively short half-life (e.g. from iodine-131 therapy) should be stored for decay in marked containers, under lead shielding, until activities have reached authorised clearance levels.

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.

2 Annex

2.1 Abbreviations and semantics

AGV	automated guided vehicle
Av.	average (arithmetic)
Bq	becquerels
cap	head (inhabitant or patient)
CFU	colony forming unit
Ci	curie
EU	European Union
EWC	European Waste Catalogue
GTZ	Gesellschaft für Technische Zusammenarbeit (German institution)
HCF	health-care facility
HCGW	health-care general waste
HCRW	health-care risk waste (hazardous and highly hazardous)
HCW	health-care waste
HCWM	health-care waste management
HIV	human immunodeficiency virus
IAEA	International Atomic Energy Agency
ICC	Infection Control Committee
ICO	Infection Control Officer
lbs	pound (English unit of weight (1 lbs = 0,45 kg))
NGO	non governmental organisation
POPs	persistent organic pollutant
PVC	polyvinyl chloride
UN	United Nations
WHO	World Health Organisation
WMO	Waste Management Officer
WMT	Waste Management Team

2.2 Glossary

antineoplastic drugs

drugs that have the specific action inhibiting and combating the development of tumours

cancerogenic

increases the probability of developing cancer diseases

cerebro-spinal fluid (or liquor)

fluid from the brain and spinal cord area

cytostatic

inhibiting or suppressing cellular growth and multiplication

cytotoxic

cytotoxic substances cause destruction action on certain cells; used in particular in referring to the lysis of cells brought about by immune phenomena and to antineoplastic drugs

disinfection

destruction of most, but not all, pathogens by different means to safe or relatively safe levels

epidemic

attacking or affecting many individuals in a relatively small area or a population simultaneously in a specific time

flue gas

exhaust gases from a combustion facility in the stack or chimney that discharges them to the atmosphere

formal sector

area of economic activities that is formally recorded by the state

genotoxic

genotoxic substances may bind directly to DNA or act indirectly leading to DNA damage; cause mutations which may or may not lead to cancer or birth defects; not necessarily carcinogenic

germ

disease-causing organism

halogenated

containing one or more of halogen elements (fluorine, chlorine, bromine, iodine)

hazardous

used for any substance and waste that pose particular danger

health-care

provision of medical care to human individuals

health-care facility

any building associated with preventive and curative medicine

health-care waste

collective term for all wastes generated by health-care facilities

heating value

define the amount of heat released when the unit mass of a material undergoes complete combustion under certain specified conditions. It is measured in units of energy per amount of material. Depending on the context, heating values may be reported as Btu/m³ , kcal/kg, J/mol. The high heating value includes the specific enthalpy of vaporisation, whereas the low heating value omits it.

hypodermic needles

hollow needle commonly used with a syringe to inject substances into the body

incineration

controlled burning of solid, liquid, or gaseous wastes to reduce volume and risks and to produce gases and residues

infection

invasion and growth of microorganisms in bodily tissues

infectious

contaminated with pathogens capable for setting, development and at best for reproduction in a host

informal sector

in contrast with the formal sector, the informal sector encompasses economic activities that are not recorded by the state

injury

physical damage to the body caused by unexpected external means

intercellular

between cells

microbial

relating to microorganisms

minimisation

any activity with the aim to reduce the quantity of waste *mutagenic*

changing the genetic information (usually DNA) of an organism

mycoplasma

group of microscopic organisms intermediate between bacteria and viruses, lacking a cell wall

nosocomial infection

infection, which originates in a health-care facility

off-site

outside the boundaries of a (health-care) facility

on-site

inside the boundaries of a (health-care) facility

pathogen

organism that can cause disease in another organism

pathogenic

disease-pounding

facultative

variable eventuality to be pathogenic

obligate

definitive pathogenic

prion

short for proteinaceous infectious particle — are infectious self-reproducing protein structures

proteinaceous

relating to or of the nature of protein

radioactive (material)

contains unstable atoms that give off [ionising] radiation as they decay

rickettsia

parasitic micro-organism, intermediate between bacteria and viruses

risk

chance of something happening that will have a negative effect

segregation

keeping hazardous waste separate from general waste at all times, the attempt to take items out of a mixed mass of waste should be avoided

sputum

matter brought up from the lungs, bronchi, and trachea that one may cough up and spit out or swallow

sterilisation

reduction in microorganisms of more than 10^6 (more than 99.9999% of the microorganisms are killed)

teratogenic

causing birth defects

throughput

quantity of waste that can be treated in a given time under certain specified conditions

vomit

matter that has come up into and may be ejected beyond the mouth, due to the act of vomiting

waste management

management of the segregation, collection, recovery, transport and disposal of wastes, including options for waste reduction.

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2.4 Picture credits

2.4.1 Lesson 1

Abb. 1:

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2.4.2 Lesson 2

Abb. 2:

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Abb. 4:

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Abb. 7, Abb. 8, Abb. 14, Abb. 17:

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2.4.4 Lesson 4

Abb. 26, Abb. 27, Abb. 28*:*

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Abb. 33:

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2.5 Questions as a learning assistance (lesson 1)

- Which items include hazardous health-care waste (examples)?
- Within which types of health-care services develop primarily general waste?
- Within which types of health-care services develop primarily hazardous waste? Give five examples!
- Why is it important to know the classification of some organisations aside from the classification of the WHO?
- Which radionuclides are mainly used in HCFs for research purposes?
- Within which source-types genotoxic waste may constitute as much as 1% of the total health-care wastes?
- Give in each case two obligatorily and facultative pathogenic infection exciters!
- Give three examples of highly infectious agents!
- What are considerable characteristic and qualitative differences between HCW being generated by the different health-care facilities?
- Give three major sources of HCW and give accessory respective performance specifications!
- Which connection exists between the income-level of a country and generation-rates of HCW?
- How much is the moisture percentage by infectious waste?
- Which one or more characteristics have hazardous HCW?
- About what is the type of hazard, which proceeds from HCW, directly dependent?
- Which persons are mostly at risk in developing countries?
- Give five reasons leading to the very high risk level for waste pickers!
- Whereby is the difference between the probabilities justified?
- Which employees are at risk while handling of hazardous chemicals?
- Why is it necessary to absorb free mercury immediately with suitable materials?
- Which types of properties contain chemicals and pharmaceuticals used in HCFs?
- For what reasons aren't dangerous chemicals allowed arriving into the sewage system?
- What has to be considered with the disposal of reactive chemicals?
- Therefore, large quantities of chemicals, particularly disinfectants, should not be discharged into a sewerage system or watercourse.

- Which transmission pathways can essentially differentiated with infectious diseases?

2.6 Questions as a learning assistance (lesson 2)

- Why have only few developing countries appropriate laws and/or regulations regarding HCWM?
- Which categories of HCW resulting in HCFs contain the Basel Convention?
- What are most important content subjects of the Basel Convention?
- Which specifications should be included in a technical guideline?
- Give three regulatory principles and the respective exemplification existing in waste management?
- Why is it necessary to draw up sheets like policy documents or technical guidelines?
- Why is it convenient to use pictures or a simple plain language while draw up a local procedure?
- What are the purposes of the IAEA?
- Why is it especially in developing countries meaningful to implement the compliance of regulatory first at hospitals with a high level of resources?
- To which organisation the IAEA is to be assigned?
- Give two sub-types or agents of the sterilisation of medical items and explain these!
- Which requirements should be paid in terms of recyclable collection?
- Which fractions of the general waste stream should be collected separately to minimise expenses under the aspect of ecology?
- Give two examples in each case to avoid or minimise waste for nursing ward, laboratory and operating theatre!
- What are the measures to avoid waste with high contents heavy metals?
- Which advantages has a central preparation of cytostatic drugs?
- Give six examples to conform and to improve the waste-management regarding the avoidance and minimisation of waste!
- What is the basis for a proper collection system?
- Which measures should be realised to minimise the amount of infectious waste generated?
- Why have to set smaller HCFs other priorities at the improvement of the waste management?

- Which components should be included in a work plan to implement HCWM improvements?
- Which further plans are to be considered during the draft and conversion of a HCWM plan if necessary?
- How can HCFs reduce the costs associated with the waste management (2 examples)?
- Give the main components of the individual costs associated with HCWM!
- Which criteria should be considered at the choice of management and disposal options?
- Which particulars should be included in sketches and/or drawings used in connection with HCWM?
- Give three individual responsibilities and the associated duties within the HCWM in large facilities!
- What are the principal purposes of a proper HCWM?
- Why should local authority representatives be invited to the meetings of the waste management team?
- What are the most important objectives associated with the waste management of the Agenda 21?
- Why it is helpful to implement necessary measures carefully?
- What are the basic measures for HCFs that setting up a comprehensive HCWM?
- Which persons should be integrated and/or new be designated into the waste management team?
- What should be considered at the selection of responsible persons?
- Who is responsible for the monitoring of the internal collection and transport of waste containers?
- Who designates the Waste Management Officer?
- What is the postulate to ensure a proper national HCWM programme?
- Wherefore subserve specific software in the domain of HCWM?

2.7 Questions as learning assistance (lesson 3)

- Which local circumstances and conditions should be taken into account by selection a waste treatment method or technology (give five criteria)?
- What circumstances led to the development of solar-powered disinfection plants (solar-cookers)?
- What is the main difference between the terms “sterilisation” and “disinfection”?

- What are the best means of keeping production of toxic gases to a minimum?
- Give some operational practices that will lead to emission reduction.
- Give the pre-conditions that will lead to formation of dioxins and furans.
- What are “POPs”?
- What are the temperatures in single-chambered incinerators temperatures are situated around 300 to 400 °C.
- At what time should occur the waste segregation in HCF? Give a brief reason.
- Outline the UN dangerous goods symbol of class 6.2.
- Give the designations which must be attached to the containers if these are transported on public roads.
- What should be noted if automatic container washing plants are used?
- For what reason should the rooms with the transmit- and receive stations on the units and departments be arranged close to the AGV lifts?
- What is the main advantage of AGV application?
- Which procedure can be applied in the case of small quantities of cytotoxic waste? What is the pre-condition?
- What are the minimum requirements on the properties of sharps containers?
- What are the main requirements on collection and transport of anatomical waste?
- Who should handle hazardous chemical waste?
- What are the components of the most common AGVs?
- Give the definitions of Category A and B agents based on the “Recommendations on the transport of dangerous goods” (14th edition).
- What is the reason that HCW containing infectious substances of category A or infectious substances of category B as cultures should be treated inside HCFs as near by the point of production as possible?
- What should be noted if general waste is be compressed in special compactors?
- What are the main measures to improve segregation efficiency and minimise incorrect use of waste containers?
- Which regulation regarding the transport of dangerous goods applies in Europe?
- Where are the packaging requirements for UN Number 2811 outlined?
- What are the consequences if general waste is mixed with infectious waste?

- Specify the demands on design of vehicles transporting HCW!
- Which off-site transport procedure is wise for small and scattered HCFs?

2.8 Questions as learning assistance (lesson 4)

- Which local circumstances and conditions should be taken into account by selection a waste treatment method or technology (give five criteria)?
- Which types of costs are included in the sum of capital costs?
- Whereof are investment (capital) costs of treatment plants dependent?
- What are the advantages of treatment with steam and microwave irradiation?
- What are far-reaching negative consequences caused by open dumping?
- What are the disadvantages of microwave irradiation?
- What circumstances led to the development of solar-powered disinfection plants (solar-cookers)?
- Specify the course of the microbiological inactivation efficacy test for infectious waste treatment plants.
- Give examples of external and internal waste management costs incurring for HCFs.
- Which process steps are necessary for the regular operation of a steam disinfection plant?
- What is the main difference between the terms “sterilisation” and “disinfection”?
- Give the theoretical contact times depending on pressure and temperature needed to achieve disinfection.
- Which problems may occur when waste shredders are used?
- What could be the reason if higher pressures than the saturation pressures of steam in steam disinfection chambers occur?
- How can be achieved the destruction of closed containers in steam disinfection chambers?
- What type of treatment ensures the highest disinfection safety?
- What are the best means of keeping production of toxic gases to a minimum?
- For what reasons are incinerators, steam disinfection and microwave irradiation plants with high throughput capacities in the majority of cases operating off-site?