Table 15.1. Classification of healthcare waste by World Health Organization

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

Source: Chartier et al., 2014; reproduced with permission from World Health Organization

manual sorting of hazardous waste from health-care establishments. These practices are common in many regions of the world. The waste handlers are at immediate risk of needle-stick injuries and exposure to toxic or infectious materials.

The transmission of infection and its control follows "chain of infection" with the following components in order (Chartier et al., 2014):

- *Infectious agent*: a microorganism that can cause disease
- *Reservoir*: a place where microorganisms can thrive and reproduce (e.g. in humans, animals, inanimate objects)
- *Portal of exit*: a means for a microorganism to leave the reservoir (e.g. respiratory, genitourinary and gastrointestinal tracts; skin and mucous membranes; and the placenta)
- *Mode of transmission*: how the microorganism moves from one place to another (e.g. contact, droplets, airborne)
- *Portal of entry*: an opening allowing the microorganism to invade a new host
- *Susceptible host*: a person susceptible to the disease, lacking immunity or physical resistance to prevent infection

Each component has unique significance and must be understood in order to prevent the transmission. Each link in the chain must be present and in the precise sequential order for an infection to occur. Breaking any link in the chain will prevent infection, although control measures for healthcare are most often directed at the "mode of transmission" stage in the chain of infection (Chartier et al., 2014).

As mentioned previously, about 10–25% of the overall HCW represents the infectious and hazardous waste. Of this hazardous wastes, infectious and anatomic wastes together is the predominant waste (Figure 15.2); thus most commonly need to be safeguarded against. Other potentially hazardous health care waste components (i.e. chemicals such as mercury in thermometers, pharmaceuticals such as cytotoxic drugs or materials contaminated with cytotoxics, radioactive waste and pressurized containers) comprise a very small fraction of the total waste quantity. Pathological wastes are generated during surgery/autopsy or other medical procedures and include human tissues, organ, body parts, body fluids and specimens along with their containers.

Infectious wastes may contain sufficient population of infectious (viral, bacterial or parasitic diseases) agents that are capable of causing and spreading infections among people, livestock and vectors. Such wastes include cultures and stocks of infectious agents from laboratory work, waste from infected patients in isolation wards, human tissues, anatomical waste, organs, body parts, placenta, animal waste (tissue/ cell cultures), any pathological/ surgical waste, microbiology and biotechnology waste (cultures, stocks, specimens of micro-organism, live or attenuated vaccines, etc.), cytological, pathological wastes, solid waste (swabs, bandages, mops, any item contaminated with blood or body fluids), infected syringes, needles, other sharps, glass, rubber, metal, plastic disposables and other such wastes. Therefore, mixing this infectious waste with other waste leads to potential risk of infection to various stakeholders dealing with the HCW. The potential infections caused by exposure to health-care wastes, causative organisms and transmission vehicles are presented in Table 15.2.

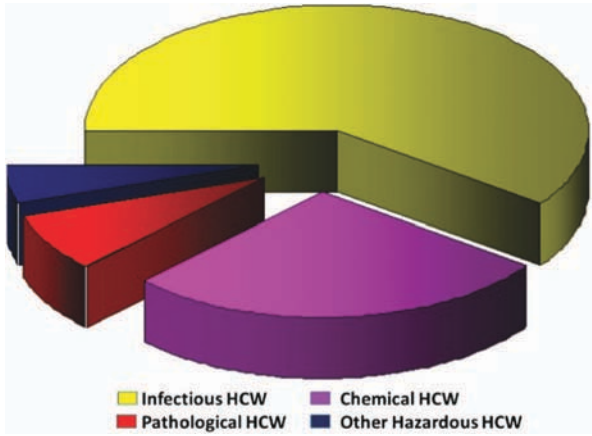

Figure 15.2. Composition of hazardous health care wastes
Source: Kühling (2014)

Table 15.2. Potential infections caused by exposure to HCW, causative organisms and transmission vehicles

Type of infection	*Examples of causativeorganisms*	*Transmission vehicles*
Gastroenteric infections	Enterobacteria, e.g. *Salmonella*, *Shigella* spp., *Vibrio cholerae*, *Clostridium difficile*, helminths	Faeces and/or vomit
Respiratory infections	*Mycobacterium tuberculosis*, measles virus, *Streptococcus pneumoniae*, severe acute respiratory syndrome (SARS)	Inhaled secretions, saliva
Ocular infection	Herpesvirus	Eye secretions
Genital infections	*Neisseria gonorrhoeae*, herpesvirus	Genital secretions
Skin infections	*Streptococcus* spp.	Pus
Anthrax	*Bacillus anthracis*	Skin secretions
Meningitis	*Neisseria meningitidis*	Cerebrospinal fluid
Acquired immunodeficiency-syndrome (AIDS)	Human immunodeficiency virus (HIV)	Blood, sexual secretions, body fluids
Haemorrhagic fevers	Junin, Lassa, Ebola and Marburg viruses	All bloody products andsecretions
Septicaemia	*Staphylococcus* spp.	Blood

(Continued)

Table 15.2. Potential infections caused by exposure to HCW, causative organisms and transmission vehicles (Continued)

Type of infection	*Examples of causativeorganisms*	*Transmission vehicles*
Bacteraemia	Coagulase-negative *Staphylococcus* spp. (including methicillian-resistant *S. aureus*), *Enterobacter*, *Enterococcus*, *Klebsiella* and *Streptococcus* spp.	Nasal secretion, skin contact
Candidaemia	*Candida albicans*	Blood
Viral hepatitis A	Hepatitis A virus	Faeces
Viral hepatitis B and C	Hepatitis B and C viruses	Blood and body fluids
Avian influenza	H5N1 virus	Blood, faeces

Source: Chartier et al. (2014); reproduced with permission from World Health Organization

15.3 WASTE GENERATION RATE

All round technological progress has led to increased availability of health related consumer goods, which have the propensity for production of increased wastes. Waste generation depends on numerous factors such as established waste management methods, type of health-care establishment, hospital specializations, proportion of reusable items employed in health care, and proportion of patients treated on a day-care basis (Prüss et al. 1999). Estimates of health care waste generation depend on the number and types of medical areas, number of beds in use in each medical area and the number of inpatients and outpatients (Cheng et al. 2009). The largest quantities of potentially infectious health care waste are produced typically in surgical, maternity, isolation and medical laboratory areas and emergency rooms. Waste production data are usually expressed as kilogram/occupied bed per day for inpatients and kilogram/appointment per day for outpatients. Total HCW generation from different countries are presented in Table 15.3.

In Hong Kong, more than 2,000 tonnes of clinical wastes are generated every year (HKEPD 2014). More stringent sorting requirements at hospitals implemented since 1992 has paid off as clinical waste requiring special handling in 2000 was about 0.13 kg/bed/day in government hospitals (Ha et al. 2000; Chung and Lo 2003). Since the general wastes are excluded, this value can be considered as the quantity of infectious and hazardous waste closely matching the value of 0.12 kg/bed/day for the year around 2007 as compiled by Emmanuel (2007). Data from 150 health care establishments in Taiwan have indicated that the average waste generation rates ranged from 2.41 to 3.26 kg/bed/day for general medical wastes, and 0.19–0.88 kg/bed/day for infectious wastes (Cheng et al. 2009). Total health care waste in a primary health care clinic may be about 0.1 kg/patient per day and that in a general hospital may be 2 kg/bed per day

Table 15.3. Comparison of hospital waste generation rates in different countries

Country	*Generation rate (kg bed^{-} 1 day^{-1})*	*Reference(s)*
Bangladesh	0.57–1.28	Sarkar et al. 2006; Alam et al. 2008
Brazil	3.2–4.5	Da Silva et al. 2005
China	1.8–2.2	Shen et al. 2003
Cambodia	0.098	Visvanathan 2008
Greece	1.9	Tsakona et al. 2007
Iran	2.75–4.58	Askarian et al. 2004; Masoumbeigi et al. 2008; Farzadkia et al. 2009; Taghipour and Mosaferi 2009; Bazrafshan and Mostafapoor 2011
Ethiopia	0.361–0.669	Debere et al. 2013
India	0.30–2.31	Patil and Pokhrel 2005; Visvanathan 2008
Indonesia	0.75	Visvanathan 2008
Jordan	0.83	Abdulla et al. 2008
Laos	0.84	Visvanathan 2008
Libya	1.3	Sawalem et al. 2009
Mongolia	0.13–0.52	Visvanathan 2008
Norway	3.9	Bdour et al. 2007
Pakistan	1.28–3.47	Pescod and Saw 1998
Palestine	1.86–2.3	Al-Khatib and Sato 2009
Portugal	3.9	Diaz et al. 2008
Spain	4.4	Bdour et al. 2007
Taiwan	2.41–3.26	Cheng et al. 2009
Thailand	1.0	Kerdsuwan 2000
Turkey	0.63	Birpinar et al. 2009
USA	2.59–5.83	Emmanuel 2007
Vietnam	1.42	Diaz et al. 2008

(Rushbrook and Zghondi 2005). Estimates say that the total quantity of medical waste, in a city like Delhi, is less than 60 metric tonne/day as compared to a total municipal waste stream of 5000 metric tonnes. Based on occupancy ratio of the hospitals, 700 g/day waste is reported per bed in hospitals at Ahmedabad. Immunization injections in India itself is estimated to be about 210 million a year, resulting in huge quantities of immunization waste (Singh 2004). Biomedical waste generated in 30 Delhi government hospitals varied from 0.78 kg/bed to 0.30 kg bed^{-1} day^{-1}. Some other hospitals have even much lesser generation rate indicating an overall average of 0.26 kg bed^{-1} day^{-1} (Visvanathan 2008).

The Table indicates that the generation rate of hospital waste differs not only from country to country but also within countries. For example, in India, the generation rate ranged between 0.30 and 2.31 kg/bed/day. The variation in waste

generation among hospitals may be attributed to a variety of reasons, such as the type of healthcare establishment, income level, welfare of patients and visitors, diversity of departments (e.g. surgical, general, pediatric), type of hospital in terms of private or public, level of instrumentation and location, hospital specialization, proportion of disposable substances used in healthcare activities and efficiency of segregation of the hazardous hospital waste from the non-hazardous hospital waste stream. It is also reported that the range of generation rate values for countries of similar income levels is probably as wide in high-income countries as in less wealthy countries (Prüss et al. 1999).

15.4 SOURCE REDUCTION AND SEGREGATION

The key to minimization and effective management of health-care waste is segregation (separation) and identification of the waste. Only 10–25% of HCW is of real concern, because of its infectious nature, indicating the importance of "Source reduction and segregation" as the key to proper medical waste management. If this waste is not properly segregated at the source of generation, the whole of the waste gets mixed up, making the whole waste infectious. Appropriate handling, treatment and disposal of waste by type reduces costs and does much to protect public health. By segregation, different categories and types of HCW are sorted and placed in different containers, enabling minimizing the amount of waste to be treated besides more efficient treatment of each category of waste.

The management of infectious waste is the responsibility of the health care institutions generating the same. The person who produces a waste item should have the knowledge to decide if it is a hazard risk or non-risk item and must have the discipline at all times to place it in the correct container. Rigorous measures for source reduction and segregation can substantially reduce the risks and ensure the safety of staff, patients, general public and the environment. Minimizing the amount of waste generated at the source itself is possible through product substitution, technology change and good operating practices. Changes in purchasing policies and product substitution can also reduce the toxicity of the waste generated. For example, mercury based thermometer can be substituted by electronic sensing devices.

Waste should be identified and segregated at the point of generation. Non-hazardous waste, such as paper and cardboard, glass, aluminum and plastic, should be collected separately and recycled. Food waste should be segregated and composted. Infectious and/ or hazardous wastes should be identified and segregated according to its category using a color-coding system. The colour coding of bins may vary according to national legislation. Typically,

- Yellow bins are used for infectious waste, like anatomical, pathological, soiled dressings contaminated with blood or other body fluids.
- Red bins are used for infected plastics like IV sets, tubing, catheters microbiological waste etc.

- Blue Glass/Stainless steel or translucent puncture proof container are recommended for metal sharps.
- Black bins are used for cytotoxic drugs, incinerator ash, chemical waste and expired medicines.
- White bins may be used for all sorts of non-infected general waste which are dry and recyclable.
- Green bins are suggested for collecting and transporting biodegradable wastes such as food waste from wards, canteens and dining halls.

Mercury is to be stored separately in sealed and impermeable containers in a secure location. Containers should be kept covered to prevent contact with the open air. Sharps and potentially infectious waste should be kept in separate containers, with well-fitting lids, either removable by hand or preferably operated by a foot pedal, in each medical area. Containers should be clearly labeled and clear signs placed on containers and bags to differentiate between general and hazardous health care waste. Practices such as having yellow bags in black bins – should be avoided, because it will increase the potential for confusion and poor segregation. A minimum of one removal from each storage point should be provided in every working shift. Thus scientific segregation practices require investments for the purchase of bins, polythene bags, hypochlorite solution, wheel barrows etc., and the recurring cost should be kept in mind while planning for waste management. It is essential that they insist on the use of clean gloves and uniforms, along with other protective clothing, face masks, or eye protection, as appropriate, by the employees to provide protection against exposure to infectious waste. It is important to keep in mind that sustaining staff motivation is threatened if segregated wastes are re-mixed during temporary storage and final treatment and disposal.

Albany Medical Center, a 500-bed research hospital in New York has recycled 7,273 tons of waste and saved the hospital $4 million in six years by recycling 43% of its total waste stream (HCWH 2001). In addition to a host of typical items it recycles, such as paper, cardboard and steel cans, the Center is also able to recycle five different types of waste chemicals into usable products through the use of a chemical distillery that can convert waste alcohol, formalin, xylene, mineral spirits and paint into pure products for use in its laboratories, reducing the waste production of hazardous chemicals from 29 tonnes to 6 tonnes and save $250,000 per year in disposal and chemical purchasing costs.

Holy Family Hospital, a 300-bed multi-specialty hospital in New Delhi, segregates its plastic waste from patient care into eight categories. Recyclers appreciate this practice as it reduces their work and they collect the different kinds of plastic, paying the hospital a good price. The hospital also reuses discarded bed sheets by cutting out the unusable portion and converting the remaining sheet into nappies to be used in its nursery, or for cloth dusters. A 600-bed multi-specialty hospital in Delhi, through an effective mercury spill management programme, has collected 1.6 kg of mercury (spilt due to breakage of thermometers and

sphygmomanometers) and returned it to a thermometer manufacturing unit (Patil and Pokhrel 2005).

15.4.1 Transport

The HCW collected for its treatment and disposal at the site should be packed as per the regulations and transported to its treatment and disposal site. For this purpose, waste is collected and segregated according to its specifications and stored for further treatment. The transport of these wastes can be classified into on-site and off-site transport. It is essential that hazardous and non-hazardous wastes should always be transported separately. In addition, infectious waste should be transported separately from hazardous waste, to prevent the possible spread of infectious agents.

15.4.1.1 On-Site Transport

Health-care waste should be transported within the hospital or other facility by means of wheeled trolleys, containers, or carts that are not used for any other purpose and meet the following specifications,

- easy to load and unload;
- no sharp edges that could damage waste bags or containers during loading and unloading and
- easy to clean.

The vehicles should be cleaned and disinfected daily with an appropriate disinfectant. All waste-bag seals should be in place and intact at the end of transportation.

15.4.1.2 Off-Site Transport

The health-care waste producer is responsible for safe packaging and adequate labeling of waste to be transported off-site and for authorization of its destination. Packaging and labelling should comply with national regulations governing the transport of hazardous wastes, and with international agreements if wastes are shipped abroad for treatment.

In general, the waste should be packaged according to the recommendations, in sealed bags or containers, to prevent spilling during handling and transportation. The bags or containers should be appropriately robust for their content (puncture-proof for sharps, for example, or resistant to aggressive chemicals) and for normal conditions of handling and transportation, such as vibration or changes in temperature, humidity, or atmospheric pressure. In addition, radioactive material should be packed in containers whose surfaces can be easily decontaminated. The United Nations recommend further packing requirements for infectious substances. For infectious health-care wastes, it is recommended that packaging should be design type-tested and certified as approved for use. Health-care wastes that are known or suspected to contain pathogens likely to cause human disease should be considered as "Infectious Substances" and should

comply with the packaging requirements. The packaging recommended for most health-care wastes, with a relatively low probability that infectious substances are present and which are not likely to cause human disease, is simpler.

15.4.1.3 Labelling

All waste bags or containers should be labelled with basic information on their content and on the waste producer. This information may be written directly on the bag or container or on preprinted labels, securely attached. For health-care waste, the following additional information should be marked on the label:

- Waste category
- Date of collection
- Place in hospital where produced (e.g. ward)
- Waste destination.

In case of problems involving questions of liability, full and correct labeling allows the origin of the waste to be traced. Labeling also warns operative staff and the general public of the hazardous nature of the waste. The hazards posed by container contents can be quickly identified in case of accident, enabling emergency services to take appropriate action.

15.4.1.4 Transportation Vehicles or Containers

Before transportation of the waste, dispatch documents should be completed, all arrangements should be made between consignor, carrier, and consignee, and, in case of exportation, the consignee should have confirmed 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.

Waste bags 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 galvanized bins). This has the advantage of reducing the handling of filled waste bags but results in higher disposal costs. These secondary containers should be placed close to the waste source. Any vehicle used to transport HCW should fulfill the following design criteria:

- The body of the vehicle should be of a suitable size commensurate with the design of the vehicle, with an internal body height of 2.2 metres.
- There should be a bulkhead between the driver's cabin and the vehicle body, which is designed to retain the load if the vehicle is involved in a collision.
- There should be a suitable system for securing the load during transport.
- Empty plastic bags, suitable protective clothing, cleaning equipment, tools, and disinfectant, together with special kits for dealing with liquid spills, should be carried in a separate compartment in the vehicle.
- The internal finish of the vehicle should allow it to be steam-cleaned, and the internal angles should be rounded.

- The vehicle should be marked with the name and address of the waste carrier.
- The international hazard sign should be displayed on the vehicle or container, as well as an emergency telephone number.

Vehicles or containers used for the transportation of health-care waste should not be used for the transportation of any other material. They should be kept locked at all times, except when loading and unloading. Articulated or demountable trailers temperature-controlled if required) are particularly suitable, as they can easily be left at the site of waste production. Other systems may be used, such as specially designed large containers or skips; however, open-topped skips or containers should never be used for transporting health-care waste. Where the use of a dedicated vehicle cannot be justified, a bulk container that can be lifted on to a vehicle chassis may be considered. The container may be used for storage at the health-care establishment and replaced with an empty one when collected. The finish of these bulk containers should be smooth and impervious and permit easy cleansing or disinfection. The same safety measures should apply to the collection of hazardous HCW from scattered small sources. Health-care establishments that practice 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.

Refrigerated containers may be used if the storage time exceeds or transportation times are long. The infectious waste should be kept cool or refrigerated at preferably in a range of 3°C to 8°C if stored for more than a week. If refrigerated storage room is not available, storage times (the time gap between generation and treatment) should not exceed 72 and 48 h for temperate climate and 48 and 24 h for warm climate in winter and summer seasons, respectively (Chartier et al., 2014).

15.4.1.5 Routing

Health-care waste should be transported by the quickest possible route, which should be planned before the journey begins. After departure from the waste production point, every effort should be made to avoid further handling. If handling cannot be avoided, it should be pre-arranged and take place in adequately designed and authorized premises. Handling requirements can be specified in the contract established between the waste producer and the carrier.

15.4.2 Risk Involved During Healthcare Waste Management

In many developing countries, HCW seldom receives due attention and often handled as part of the municipal waste stream. Physicians, healthcare staff and workers often do not realize the flipside of their negligence and the disorder it causes later. Nevertheless, awareness of the perceived and real problems of handling and disposal of HCW is now increasing. While procedures for proper HCW management are lavishly discussed, not much thought has gone into disseminating the health risk arising from poor management of HCW. A rapid