Kingdom of Cambodia

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Ministry of Health

Technical Guidelines on Healthcare Waste Management

Prepared By
Debbie Siru
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Preface

Birth, death and disease are part and parcel of a man's existence. Man's quest to seek a cure for illness evolved from belief in witchcraft, demonic forces and astral influences to a more systematic study of cause and effect, which lead to the science of medicine. With greater acceptance and recognition of diagnosis, prognosis, physical examination and medical prescriptions, special places began to be established for the purpose of treating patients. Thus it has been documented that healthcare establishments (HCEs) date as far back as the Egyptian civilisation, i.e. around 3000 B.C.

Today HCEs co-exist with other commercial entities as an integral part of our civilisation. However, HCEs of today are far more complex than the HCEs of ancient Egyptian civilisation. Great advancements have been made since then with respect to healthcare technology, diagnostic and therapeutic techniques and pharmaceutical formulation. While these have a positive impact on the way we are able to cure disease and improve the quality of life after the onset of illness, the existence of HCEs as with all things on the planet has an impact on the environment. While approximately 80% of the wastes generated in an HCF are general waste, the remaining 20% comprise wastes that contain harmful microorganisms which can infect hospital patients, health-care workers and the general public, as well as sharp objects and hazardous substances that can result in injuries, poisoning and pollution.

Indiscriminate disposal of healthcare waste can also result in scavenging and re-use of needles and syringes. The manual sorting of waste itself has the potential to cause injury to scavengers with the potential of exposure to infection while the hazards relating to re-use of needles and syringes is very real. WHO estimates that 8 to16 million Hepatitis B, 2.3 to 4.7 million hepatitis C, and 80,000 to 160,000 HIV infections, are estimated to occur yearly throughout the world from re-use of syringe needles without sterilization. Less of a public health threat but which is nevertheless a risk is the scavenging of expired pharmaceuticals and its subsequent diversion for re-sale and reuse. While most expired drugs are merely less efficacious beyond its expiry date, some have the potential to cause adverse drug reactions and poisoning.

Recognising the deleterious effect that poor management of healthcare waste can have on the environment and on human health, the Ministry of Health, Kingdom of Cambodia formulated the Regulations on Health-care Waste Management in Cambodia in July 2008. This guideline has been prepared to support the effort of the Ministry of Health by providing technical specifications for specific components of healthcare waste management. In the preparation of this guideline, consideration has also been given to the Cambodian Ministry of Health's policy on healthcare waste management as well as the Cambodian Ministry of Environment's Law on Environmental Protection and Natural Resource Management and its Sub-Decree on Solid Waste Management.

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List of Terms and Acronyms

APC	Air pollution control
BOR	Bed occupancy rate
BTU	British Thermal Unit
CHWS	Central healthcare waste store
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
HCE	Healthcare establishment
HCW	Healthcare waste
HCWM	Healthcare waste management
HIV	Human immunodeficiency virus
LEPNM	Law on Environmental Protection & Natural Resource Management
MOE	Ministry of Environment
MOH	Ministry of Health
NIOSH	National Institute of Occupational Safety and Health
PCC	Primary combustion chamber
PPE	Personal protective equipment
SCC	Secondary combustion chamber
PHCWM	Prakas on Healthcare Waste Management
SEIA	Sub-Decree on Environmental Impact Assessment
SSWM	Sub-Decree on Solid Waste Management
SW	Solid waste
SWM	Solid Waste Management
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation

1. Introduction

This guideline provides technical specifications for specific components of healthcare waste management (HCWM), i.e.:

a. Temporary storage area for healthcare waste (HCW)
b. Encapsulation facility
c. Secure landfill
d. Incineration facility

It is not the intention of this guideline to provide engineering designs and specifications for these components. The approach of this guideline is to provide decision makers with a guide on:

a. Factors that must be considered before these components of healthcare waste management are installed and implemented.
b. Criteria that must be incorporated into the design of these components.

The successful implementation of this guideline would hinge on the successful implementation of critical HCWM activities such as segregation, labeling, collection etc. While these critical activities are described in the Regulation (Prakas) on Healthcare Waste (PHCWM) additional requirements, clarifications and amendments are necessary for better understanding and for more effective and successful implementation of the regulation. Thus, for completeness relevant requirements as described in the PHCWM are reproduced in this guideline together with the additions, clarifications and amendments.

The successful implementation of this guideline would also hinge on improvement of resources, infrastructure, technical competence and governmental controls. These are however not covered in this guideline.

This guideline is based on a review of various scientific and technical resources. It is not intended to be a step-by-step procedure on the various activities of healthcare waste management. It is also not intended to be a comprehensive set of procedures for the operation of the above-mentioned components nor does it describe applicable legal requirements, which would vary on the location of the HCEs and these components. Proper operation of these components is the responsibility of the owner and/or operator.

Mention of trade names or commercial products, and pictures or drawings, if any, do not constitute endorsement or recommendations for use or adoption.

2. Definition of Terms

TERM	DEFINITION
Antineoplastic	Preventing the development, maturation, or spread of neoplastic cells
British Thermal Unit	A traditional unit of energy equal to about 1055 joules. A BTU is defined as amount of heat required to raise the temperature of one 1 pound (0.454 kg) of liquid water by 1 °F (0.556 °C) at a constant pressure of one atmosphere
Buffer zone	An area that lies between two or more other areas
Carcinogenic	An agent that can cause cancer
Composting	Composting is a natural biological process resulting in the breakdown of organic matter into valuable organic fertilizer. This process is carried out under controlled aerobic conditions (i.e. requiring oxygen) and the breakdown is achieved by various microorganisms.
Contingency Plan	Plan to ensure the continued ability to deliver the service during planned extensive periods of downtime and/or unforeseen circumstances.
Emergency Response Plan	Plan that coordinates and integrates all activities necessary to build, sustain, and improve the capability to mitigate against, prepare for, respond to, and recover from threatened or actual natural disasters, acts of terrorism, or other man-made disasters.
Flammable	Easily ignited and capable of burning rapidly; inflammable.
Flood plain	A flat or nearly flat land adjacent a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge
Fly ash	Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases or is the ash that produced during combustion of coal
Genotoxic	Damaging to DNA and thereby capable of causing mutations or cancer.
Hazard	A possible source of danger, harm or injury
Healthcare establishment	As defined in the PHCWM, it includes but not limited to, all government and private hospitals, health centres, medical and biomedical laboratories, biotechnology laboratories and institutions, medical research centres, animal research and testing, blood banks, nursing homes for the elderly, mortuaries and autopsy centres, dental clinics, home health care, acupuncturists, psychiatric clinics, illicit drug users, funeral services, paramedic services and institutions for disabled person, veterinary centres

TERM	DEFINITION
	and other establishments where healthcare wastes are generated.
Healthcare waste	As defined in the PHCWM, it includes all categories of waste generated by a healthcare establishment (HCE)
Leachate	Any liquid material that drains from land or stockpiled material and contains significantly elevated concentrations of undesirable material derived from the material that it has passed through
Mutagenic	An agent that can induce or increase the frequency of mutation in an organism
Neoplasia	Abnormal growth of cells, which may lead to a neoplasm, or tumor.
Pathogens	An agent that causes disease, especially a living microorganism such as a bacterium, virus, or fungus
Pozzolanic	Having the properties of a pozzolan. A pozzolan is a material which, when combined with calcium hydroxide, exhibits cementitious properties.
Radioactivity	Spontaneous emission of radiation, either directly from unstable atomic nuclei or as a consequence of a nuclear reaction. The radiation, including alpha particles, nucleons, electrons, and gamma rays, emitted by a radioactive substance.
Radionuclide	An atom that exhibits radioactivity
Roentgen	A unit of measurement for exposure to ionizing radiation (such as X-ray and gamma rays)
Sharps container	A container that has been designed and constructed for the safe disposal of sharps; sometimes known as safety boxes
Stoichiometric	Concerned with, involving, or having the exact proportions for a particular chemical reaction indicated by its formula
Surface runoff	The water flow that occurs when soil is infiltrated to full capacity and excess water from rain, melt-water, or other sources flows over the land
Teratogenic	An agent that can cause malformations of an embryo or fetus
Toxic	Capable of causing injury or death, especially by chemical means
Uptime	A measure of the time a machine or plant has been up and operational. Normally measured on an annual basis
Weighbridge	Large scales, usually mounted permanently on a concrete foundation that are used to weigh entire vehicles and their contents. By weighing the vehicle both empty and when loaded, the load carried by the vehicle can be calculated

3. Critical Healthcare Waste Management Activities

3.1. Waste Categories

3.1.1. Healthcare waste is broadly categorized into two main groups, namely Medical Wastes and General Wastes.

3.1.2. General wastes

- Any waste that are solid or semi-solids generated from HCEs that are non-toxic and non-hazardous and are not contaminated with medical wastes. These are the food wastes, paper, plastics, textiles, ferrous and non-ferrous metals, glass and garden wastes.
- In the event that general wastes are contaminated or mixed with any medical wastes, the general wastes shall be classified as medical wastes and managed accordingly.

3.1.3. Medical wastes

- Any waste which consists wholly or partly of human or animal tissue, blood or other body fluids, excretions, drugs or other pharmaceutical products, swabs or dressings, syringes, needles or other sharps instruments, being waste which unless rendered safe may prove hazardous or cause infection to any person coming into contact with it.
- Any other waste generated from healthcare activities which may be hazardous or toxic.
- The categories of medical wastes are:
    1. Infectious wastes
    2. Pathological wastes
    3. Sharps wastes
    4. Pharmaceutical wastes
    5. Genotoxic wastes
    6. Chemical wastes
    7. Wastes with high content of heavy metals
    8. Pressurized containers
    9. Radioactive wastes

3.1.4. Infectious wastes are all wastes suspected to contain pathogens (bacteria, viruses, parasites or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts such as, but not limited to excreta, tissue, body parts contaminated with pathogens, utensils and equipment contacted with infected patients, cottons and material trials from laboratories.

3.1.5. Pathological wastes are all wastes consisting of tissues, organs, human fetuses or various human body parts such as, but not limited to, bloods, lymph, organs or body parts of animal trials, human body liquids from surgery and autopsy. This is a sub-category of infectious waste.

3.1.6. Sharps wastes are any items that could cause cuts or puncture wound. These include needles, hypodermic needles, scalpel and other blades, knives, infusion sets, saws, broken glass and nails or other infectious sharps.

3.1.7. Pharmaceutical wastes include but are not limited to, expired, unused, spilt, and contaminated pharmaceutical products, drugs, vaccines and sera that are no longer required and need to be disposed of.

3.1.8. Genotoxic wastes are hazardous wastes that may have mutagenic, teratogenic, or carcinogenic properties. They may include, but not limited to, cytostatic drugs, vomit, urine, or faeces from patients treated with cytostatic drugs, chemicals, and radioactive materials. Apart from cytostatic drugs, there is now evidence that there are many other pharmaceuticals that exhibit adverse biological effects. The *NIOSH List of Antineoplastic and Other Hazardous Drugs in Healthcare Settings 2010* are reproduced as a guide in **Appendix 1**. This list is not exhaustive nor is there a consensus. Thus consultation with pharmacologists and toxicologists would be required before setting policies on this.

3.1.9. Chemical wastes are wastes that are solid, liquid and gaseous chemicals which may be hazardous and have at least one of the following properties:

- Toxic
- Corrosive (e.g. acids of pH<2 and bases of pH>12)
- Flammable
- Reactive (explosive, water reactive, shock sensitive)

3.1.10. Wastes with High Content of Heavy Metals are a sub category of chemical wastes and are usually highly toxic. Examples are mercury wastes from broken chemical thermometers, blood pressure gauges and cadmium wastes from discarded batteries.

3.1.11. Pressurized container wastes are emptied or unused gas cylinders, gas cartridges, aerosol cans that may explode if incinerated or accidentally punctured.

3.1.12. Radioactive wastes include solid, liquid and gaseous wastes contaminated with radionuclides which are used for diagnostic, treatment and research.

3.2. Waste Segregation

3.2.1. All HCEs shall sort and segregate healthcare waste at their source of generation into medical and general wastes. General wastes that are inadvertently mixed with medical wastes shall be considered as medical wastes and shall be handled and treated accordingly.

3.2.2. Medical wastes should preferably be segregated according to the 9 categories as described in section 3.1. If this is not possible, the following minimum levels must still be maintained:

1. Infectious wastes and pathological wastes
    - Pathological wastes are a sub-set of infectious wastes, both of which can be effectively treated by incineration.

2. Sharps wastes
    - Sharps wastes have the potential to cause injury, thereby opening a portal for infection and should therefore never be mixed with other waste categories.

3. Chemical, pharmaceutical & genotoxic wastes
    - Genotoxic wastes should not be combined with radioactive wastes for the following reasons:
        - Genotoxic wastes, unlike radioactive wastes, can be treated by incineration if incinerators are operated correctly.
        - Radioactive wastes need to be contained in lead-lined containers. These are often limited in numbers. Combining genotoxic waste, which do not need to be lead-lined, is not effective use of these lead-lined containers.
    - Genotoxic, pharmaceutical and chemical wastes may be combined as one waste stream although proper labelling and sealing of genotoxic waste is essential.

4. Wastes with high content of heavy metals
    - Unlike other hazardous chemical wastes, heavy metals cannot be treated by incineration as incineration will cause the release of these toxic metals into the atmosphere.
    - These wastes should be segregated from other hazardous chemical wastes and sent to facilities that can recover the heavy metals or encapsulates and/or renders them inert.

5. Pressurized containers

   - Pressurised containers other than aerosol cans need to be handled carefully as they can explode or cause fires. Sudden release of residual gas or pressure can turn the cylinders into flying rockets and valves into projectiles, causing injury and damage.

6. Radioactive wastes

   - Since incineration does not affect radioactive properties, radioactive waste should be segregated as a stand-alone waste stream and should not be combined with other waste categories.
   - All radioactive wastes including low level radioactive infectious waste should be contained within a secondary container that is lead-lined to allow for decay to reach safe radiation levels of less than 2.5mR/hr before it is collected and treated as infectious waste. For low level radioactive waste, this is normally achieved after 10 half-lives.

3.2.3. General waste

a. Although general waste may be discarded into a municipal landfill, segregation of this waste stream is encouraged in line with the Ministry of Environment's National 3R Strategy.

b. The segregation involves separating the recyclable waste materials from the non-recyclable waste materials and organic waste.

c. Examples of recyclable waste materials are plastics, paper and e-wastes.

d. Organic waste from kitchens can be sent for composting or sent to the municipal landfill.

3.3. Colour Coding, Markings and Symbols

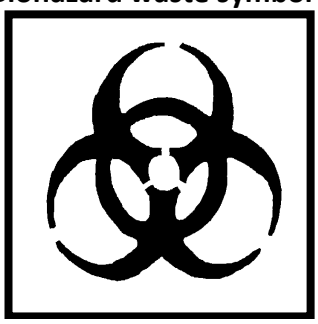
3.3.1. All HCEs shall use the standard colour coding and marking system for bags and containers for medical wastes and general wastes. These are:

Waste Category	Colour of Container & Markings	Proposed Symbol
Infectious waste	Yellow, marked black	Biohazard
Pathological wastes	Yellow, marked red	Biohazard
Sharps	Yellow, marked "SHARPS"	Biohazard
Chemical & pharmaceutical waste	Brown, marked "HAZARDOUS"	Toxic

Waste Category	Colour of Container & Markings	Proposed Symbol
Wastes with high content of heavy metals	Brown, marked with the specific heavy metal content and "HAZARDOUS"	Toxic
Genotoxic waste	Brown, marked "CYTOTOXIC"	Cytotoxic
Radioactive waste	Red	Radioactive
Pressurized containers	Black	Explosive
General waste	Black	

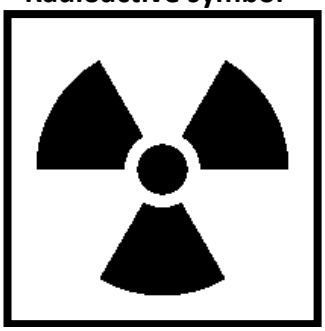
3.3.2. The relevant symbols are shown below:

Biohazard waste symbol

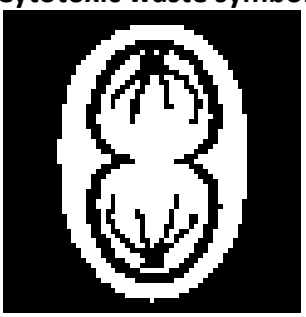


Toxic waste symbol

Radioactive symbol



Cytotoxic waste symbol



The words "CYTOTOXIC" may be added

3.4. Primary Containers

3.4.1. All HCEs shall provide enough waste bags and containers with appropriate size and correct characteristics for effective segregation to be done at the source of generation. The waste bags and containers for the different categories of healthcare wastes are as follows:

Waste Category	Type of Container
Infectious wastes, pathological wastes	Strong, leak-proof plastic bags with strong leak-proof containers to hold these bags and the wastes contained in them
Sharps wastes	Leak and puncture-proof containers
Chemical and pharmaceutical wastes	1. Solid pharmaceutical wastes: Strong, leak-proof plastic bags. Strong containers should be provided to hold the bags and the wastes contained in them 2. Liquid pharmaceutical wastes: Leak and puncture-proof containers 3. Solid and liquid chemical wastes: Leak and puncture-proof containers 4. Genotoxic wastes: As above but separate from other pharmaceutical and chemical wastes
Wastes with high content of heavy metals	Puncture and corrosive proof containers with separate containers for different metal contents
Radioactive wastes	Lead box, labeled with the radioactive symbol
Pressurized containers	Plastic bag; could mix with the general wastes – applicable to aerosol cans only
General waste	Plastic bag

3.4.2. Additional Specifications for Infectious and Pathological Waste Containment:

a. Bags and containers for infectious and pathological wastes shall be marked with the biohazard symbol.

b. Bags made of polyvinyl chloride (PVC) shall not be used.

c. Bags should have a minimum gauge of 225 (55 microns) if of low density, or minimum gauge 100 (25 microns) if of high density, or of equivalent standards.

d. Bags for packing wastes to be autoclaved shall be made of material that can withstand the maximum autoclave temperature of 270°F (132°C).

e. The size of bags should correspond with the size of containers and vice-versa so that the base of the bag rests on the base of the container and the bag can be

folded over the lip of the container. This will prevent stretching of the bag and possible tear and rupture of the bag seam.

f. The seal creep or seam should be strong and leak-proof and should not separate when loaded with waste.

g. The containers should be durable and designed for long life performance and repeated washing.

h. The containers should be lined with bags before wastes are discarded into them.

i. The containers should be smooth and easy to clean.

j. The containers should be provided with self-closing lid to contain odours. The opening of the lid should be 'hands-free operated', e.g. with foot-pedal.

3.4.3. Additional Specifications for Sharp Waste Containment:

a. Rigid, puncture resistance and leak proof.

b. Be capable of being handled and moved without contents being spilled.

c. Be provided with handle(s) that is not part of any closure device and must not interfere with normal use of the container. However exceptions to this requirement may be considered if test results or certificates of testing can be provided to show that the closure device with the handle attached is sufficiently secure.

d. Be provided with an aperture, which under normal use, will inhibit removal of contents.

e. Have a closure device that can seal the container when the container is ready to be collected for disposal.

f. Have a horizontal line to indicate when the container is ¾ full, and marked with the words "WARNING – DO NOT FILL ABOVE THE LINE".

g. Be made of materials which can be incinerated.

h. Be coloured YELLOW.

i. Be clearly marked with the words "SHARPS ONLY"

j. Be clearly marked with the biohazard symbol.

k. Safety and hygiene considerations that should be observed are:

- Containers should be assembled correctly before being put to use. Attempting to assemble the container after it is filled with sharps may result in injury and should not be practised.
- Sharps containers should be installed as close to point of use as practicable.
- Containers should be secured where possible, preferably by mounting on walls at appropriate height so that the container opening and fill line is

visible. However when mounting sharps containers, the following should be avoided:

- Do not mount sharps containers at high traffic areas. This is to avoid sharps containers from being knocked over resulting in spillage and possible injury.
- Do no mount sharps containers on gurneys, on corners or edges of cart surfaces that may collide with walls, doorjambs, rails etc.

- The capacity of sharps container should correspond with the amount of sharps used at a particular area so that containers are not used beyond 1 week.
- Do not clean soiled sharps containers. These should be collected and sent for treatment if soiled, even if the container has not been filled to the fill line.
- Do not place sharps containers on the floor, under the sink, in a cabinet or where it can be knocked over or reached by a child.

3.4.4. Additional Specifications for Chemical Waste Containment:

a. The containers used for hazardous chemical wastes must be compatible with the waste and must not contain residues of incompatible wastes. The original bottles or containers may be used to collect these wastes.

b. When using the original containers, the old label must either be completely removed or completely covered with a new label that clearly identifies the contents as wastes. This is to avoid confusion.

c. If empty original containers are not available, the purchase and use of containers to collect and store hazardous chemical wastes should be in accordance with these general principles:

Chemical Category	**Container Type**
Mineral Acids	Plastic
Bases	Plastic
Oxidizers	Glass
Organics, including acetic acid	Glass

d. The following groups of chemical wastes are incompatible should not be mixed together in a container. These are:

- Acids and bases.
- Organics and acids.
- Cyanide, sulfide or arsenic compounds and acids.

- Alkali or alkali earth metals, alkyl lithiums etc. and aqueous waste.
- Powdered or reactive metals and combustible materials.
- Mercury or silver and ammonium containing compounds.

e. In addition to the incompatible waste groups above, mixing of the chemicals within these groups into the same container should not be done. Examples are the different acids, bases, heavy metals, oxidizers etc.

f. Chemical wastes produced from a test where various chemicals had been mixed according to the testing protocol should also be put in a separate bottle.

g. All containers should be labeled with the relevant warning symbols and the words "Hazardous Waste" and the start date of generation.

h. The contents should be listed with the pH.

i. All containers must have a cap that fits tightly.

j. For liquid waste, a space of 1 inch should be left at the top of the container.

k. The outside of the container must be clean and dry.

3.4.5. Additional Specifications for Genotoxic Waste Containment:

a. Plastic bags or leak and puncture-proof containers should be used accordingly for solid and liquid genotoxic wastes and for sharps contaminated with genotoxic wastes.

b. Double bagging of genotoxic wastes may be practiced to ensure better containment.

c. To distinguish these wastes from other chemical wastes, the cytotoxic waste symbol should be displayed on the bags and containers including the words "CYTOTOXIC WASTES".

d. Sealing of the bags and containers must be done carefully and this should preferably be done by the clinical staff that are better trained and would have the appropriate PPE to handle this.

3.4.6. For wastes with high content of heavy metals, the name of the metal should be identified on the containers.

3.4.7. Wheeled bins

a. At high waste generating areas, wheeled bins may be located at these areas.

b. The location and use of wheeled bins at high waste generating areas does not preclude the need to first contain the wastes in primary containers. Hence infectious wastes, for example, should first be bagged in yellow bags marked with the biohazard symbol and sealed before it is placed in the wheeled bin. This is important to minimize cross contamination and injury.

c. Wheeled bins should also be colour coded and labeled with the appropriate symbols to ensure correct segregation of wastes.

3.4.8. Other than aerosol containers, pressurized containers should not be bagged along with general wastes due to possible fire and explosion hazards. It is strongly recommended that arrangements are made with the original gas vendors for collection of pressurized containers for reuse and recycling.

Examples of containers for healthcare wastes are shown in **Appendix 2**.

3.5. Labelling

3.5.1. For infectious, pathological waste and infectious sharps waste, the following information should be provided on waste bags:

a. Name of HCE and contact number

b. Date of packaging

3.5.2. For other medical wastes, the following information should be provided on all medical waste bags and containers:

a. Date of packaging

b. Name of HCE and contact number

c. The first date of generation

d. The category of waste, type of heavy metal etc.

3.5.3. This labelling may be done by any of the following methods:

a. Writing the information on the bag

b. Using pre-printed tape

c. Using pre-printed self adhesive address labels supplied on a peel-off roll

d. Tie on tag labels on which the information may be written on them.

3.5.4. To encourage correct labeling, it is preferable that the name of the HCE and contact details are pre-printed and only the date of packaging, date of generation, name of heavy metal need to be recorded on the label.

3.6. Waste Collection within HCEs

3.6.1. Collection of wastes from the areas within an HCE should be carried out using suitably designed trolleys and follow pre-determined collection route and collection time.

3.6.2. These trolleys should be designed and constructed so that:

a. They do not have sharp edges that could tear open waste bags during loading and unloading.

b. They are able to contain any leakage from damaged waste bags.

c. They can be easily cleaned, disinfected and drained.

d. The waste may be easily loaded, secured and unloaded.

e. Trolleys should be easily manoeuvrable with silent wheels.

f. Trolleys used for collecting infectious wastes and sharps:

- Should be rigid in construction, leak-proof, puncture resistant and reusable.
- Should be fitted with a lock and be tamper-proof.

3.6.3. The trolleys used for the collection of wastes shall be dedicated. Hence,

a. Trolleys used for collecting medical wastes should not be used for collecting general wastes.

b. Trolleys used for collecting infectious wastes and sharps should not be used for collection of other medical wastes.

3.6.4. The trolleys used for collection of wastes should be:

a. Cleaned regularly. Trolleys used for collection of infectious wastes in particular should be washed and disinfected daily and / or when the trolleys have been emptied and before they are used again for the next round of collection.

b. Cleaned and disinfected immediately following spillage.

3.6.5. Degradable medical and general wastes shall be collected daily from all sources of generation, or more frequently in high generation areas.

3.6.6. For non degradable medical wastes, the frequency need not be as frequent and should be determined depending on the amount of wastes generated. The rationale for this are:

a. The generation of some waste categories may not warrant such frequent collection. For example:

- Sharp wastes generated at some wards may not be high enough to fill the sharps container within a day. In such cases daily collection would increase the number of containers used and therefore the costs.
- With prudent use and management of pharmaceuticals and chemicals, the amount of this waste category may be small and hence daily collection may not be warranted.

b. The number of personnel necessary for daily collection of small amounts of wastes may not be the best utilization of human and financial resources. Thus

available personnel can be deployed for other tasks such as the washing of primary containers, collection trolleys and storage areas, for record keeping etc.

3.7. Waste Storage

3.7.1. A central storage area should be provided to temporarily store wastes collected from the various wards and departments before they are treated on-site or loaded onto trucks for transportation to an off-site treatment facility.

3.7.2. Since space is often limited within an HCE, it would be acceptable to locate both general and medical wastes stores in the same location provided that the two stores are clearly separated and with appropriate signs and symbols to distinguish between them.

3.7.3. All bags of solid medical waste should be contained in containers to prevent possible leakage and contamination. If there are sufficient collection trolleys, these may be used to contain the wastes until the wastes are treated or transported to a treatment and disposal facility.

3.7.4. Technical specifications for the central storage area will depend on various factors such as waste generation, whether wastes will be transported out to a treatment facility or treated on-site as well as the availability and reliability of transportation. Please see Chapter 4 for the technical specifications.

3.8. Cleaning of Waste Storage Areas

3.8.1. The storage areas for these containers or collection trolleys shall be cleaned with proper disinfectants, preferably each time after these containers or trolleys are collected or emptied for treatment and disposal.

3.8.2. A schedule of cleaning of the waste storage areas should be determined by the WMT and posted in the waste storage area.

3.9. Waste Transportation from HCE to Treatment Facility

3.9.1. Vehicles used for transportation of medical wastes from the HCE to a treatment facility shall be vehicles that have been approved by the relevant authorities.

3.9.2. The contractor providing transportation services should be able to produce a permit which should list the following information:

a. The name of HCEs it is permitted to transport waste for

b. The type of waste categories it is permitted to transport

c. The name of the treatment facility(ies) it is permitted to send the wastes to

d. The number of vehicles and registration numbers

e. The names the drivers and waste handlers

f. The routes from the HCEs to the treatment facility(ies)

g. Other relevant requirements as may be stipulated by the relevant authorities

3.9.3. The contractor shall prepare and submit Emergency Response Plans (ERP) and Contingency Plans (CP) upon submission of application for the permit.

3.9.4. The contractor should periodically review its operations and address needs due to increasing HCEs it services and increasing waste generation. This may include increasing treatment capacities, size of the fleet, number of personnel and transportation frequencies.

3.9.5. The personnel of the contractor should be trained regularly so that they are able to:

a. Recognise the different symbols and colour codes of medical wastes

b. Understand the hazards of the medical wastes being handled and take necessary precautions

c. Load and unload wastes safely

d. Fill up the consignment notes correctly

e. Execute the ERP and CP in the event of an untoward incident such as road accident, spillage etc.

3.9.6. Waste bags should preferably be placed in containers before loading wastes onto the vehicles.

3.9.7. The design criteria for vehicles shall be as follows:

a. The body of the vehicle should be of suitable size commensurate with the design of the vehicle with an internal body height of 2.2 m.

b. There should be a bulkhead between the drivers' cabin and the vehicle body.

c. There should be a suitable system for securing the load during transportation.

d. Empty plastic bags, suitable protective clothing, cleaning equipment, tools and disinfectant, together with special kits for dealing with liquid spills, should be carried in a separate compartment in the vehicle.

e. The vehicle should be marked with the name and address of the waste carrier.

f. The relevant international hazard symbols should be displayed on the vehicle or container as well as an emergency number.

g. Vehicles or containers used for the transportation of medical wastes should not be used for the transportation of any other materials. They should be kept locked at all times except when loading and unloading.

h. A bulk container that can be lifted on to a vehicle chassis may be considered for storage and replacement when full.

i. Refrigerated containers should be used if the time to transport infectious and pathological wastes to the treatment facility exceeds 24 hours.

j. If a store at the HCE does not have a loading and unloading dock, the vehicle serving such HCEs should have a tailgate that can be lowered and lifted mechanically for safe loading and unloading of wastes. See **Appendix 2** for an example.

3.10. Documentation

3.10.1. A consignment note system should be implemented when wastes are transported out from an HCE to a treatment of disposal facility.

3.10.2. The purpose of a consignment note system is to track the movement of waste and to ensure that wastes are sent to an approved treatment and disposal facility. Thus the following copies and distribution are necessary:

a. Upon collection by the transporter:
   - One copy to be retained by the HCE
   - One copy to be sent to the relevant authority by the HCE
   - One copy to be retained by the transporter

b. Upon reaching the final treatment and disposal facility:
   - One copy to be sent back to the relevant HCE, within 30 days of receipt of waste
   - One copy to be sent to the relevant authority, within 30 days of receipt of waste
   - One copy to be retained by the treatment and disposal facility

3.10.3. If the second copy is not received by the HCE within the stipulated timeframe, the HCE should investigate and report back to the authority as to the status and location of the wastes. This is to ensure that medical wastes have been sent to the approved treatment or disposal facility and have not been illegally dumped.

3.10.4. The consignment note should document the following information:

a. Name and address of HCE

b. Name and contact details of responsible person, e.g. HCE Director

c. Type of waste

d. Number of containers, drums etc.

e. Quantity of waste
   - Weight in kilograms for solid waste
   - Volume in litres and weight in kilograms for liquid waste

f. Name, address and contact details of the transporter

g. Name of the driver and vehicle number

h. Name, address and contact details of the final treatment and disposal facility

i. Treatment method

3.10.5. For periodic review of the WMP and to assess resources required, the following data should be recorded:

a. Daily generation by categories of waste

b. Daily generation by wards and departments existing in the HCE. (This needs to be done in the initial stages only).

c. This assessment should take note of cyclical variations in patient loads, occurrence of epidemics and other emergencies that may affect waste generation.

3.10.6. A quarterly report should also be prepared and forwarded to the relevant authorities. This quarterly report should be prepared by the HCE and the information required are:

a. Type and amount of waste

b. Temporary storage method

c. Treatment and disposal method.

3.11. Hygienic and Safety Precautions

The hygienic and safety precautions to be observed in relation to storage and collection of healthcare wastes are as follows:

a. Forceps or gloves should always be used to collect and deposit healthcare wastes into bags or containers.

b. Healthcare wastes and in particular medical wastes should fill around a third quarter of the plastic bags or containers and when this level is reached, the bags or containers should be securely tied or closed. The waste storage bags and containers should be checked to ensure that they are effectively sealed.

c. Healthcare waste bags shall only be used once and shall not at any time be reused.

d. Healthcare personnel must clean their hands each time after depositing the healthcare wastes in bags or containers or after collection of these bags and containers.

e. The origin of the wastes, i.e. wards or departments, should be marked on the waste bag or container. This is necessary so that the source of incorrect segregation can be identified and re-education of relevant personnel in these wards and departments can be conducted.

f. Hypodermic needles which are not properly segregated into correct sharps containers can cause needlestick injuries. Hence the following precautions shall be observed when collecting bags of wastes:

- Bags should be picked up by the neck only and placed so that they can be picked up by the neck again for further handling. Manual handling of the waste bags should be minimized wherever possible.
- Bags should not be clasped against the body nor should collection personnel attempt to carry too many at a time.
- Collection personnel should avoid hitting the bag against the body when carrying the waste.

g. Sharps have been known to pierce the sides and bottoms of sharps containers. Hence, the following precautions in relation to sharps containers shall be observed:

- Sharps containers shall be picked up and carried only by the handle provided. The other hand should not be used to support the bottom of the container.
- Sharps containers shall not be shaken to make room for more sharps.
- Sharps containers shall not be wiped. These should be discarded if heavily soiled even if the fill line has not been reached.
- Sharps containers shall not be emptied and reused unless the container is designed for this purpose and a mechanical device is available for safe opening of the sharps container.

h. Medical and general waste bags shall not be mixed and these bags and containers shall be kept in specific storage areas and not left in open spaces.

i. Collection personnel shall be trained on appropriate cleaning and disinfection procedures in case of accidental spillage and how to report an accident.

j. If there is fear of tearing and subsequent spillage, double bagging of wastes should be considered.

k. Genotoxic wastes should be sealed before collection personnel are requested to remove them.

l. Waste bags shall not be punctured to allow compacting additional waste bags into collection trolleys.

m. All collection personnel should don PPE before commencing collection. These are masks, gloves, aprons and safety boots (see **Appendix 2**).

3.12. Treatment and Disposal of Medical Wastes

3.12.1. Treatment and disposal technologies shall be approved by the relevant authorities before these are installed and used.

3.12.2. If an HCE sends medical wastes to an off-site treatment facility(ies), these facilities shall have the necessary permits from the relevant authorities.

3.12.3. The contractor providing treatment and disposal services should be able to produce a permit which should list the following information:

a. The name of HCEs it is permitted to receive wastes from

b. The type of waste categories it is permitted to receive, treat and dispose

c. The type of treatment facility for the categories of wastes it is permitted to treat and dispose

d. The capacities of the treatment facilities utilised

e. The emission limits it needs to comply with and the frequency of testing to demonstrate compliance

f. Other relevant requirements as may be stipulated by the relevant authorities

3.12.4. Wastes received at a facility for storage and treatment should be managed on the FIFO basis. This is to avoid prolonged storage.

3.12.5. The contractor shall prepare and submit Standard Operating Procedures (SOPs), Emergency Response Plans (ERP) and Contingency Plans (CP) upon submission of application for the permit.

3.12.6. The contractor shall prepare a maintenance schedule for their treatment facility(ies) and have the necessary preventive and breakdown maintenance and spare parts contracts to minimize downtime of its facility(ies).

3.12.7. The contractor shall provide quarterly reports to the relevant authorities on:

a. Type and amount of waste received for treatment and disposal

b. The type and amount of waste received by HCEs

c. Treatment and disposal method employed for these wastes

d. Incidents, if any

3.12.8. The contractor should periodically review its operations and address needs due to increasing HCEs it services and increasing waste generation. This may include upgrading capacities of temporary waste stores and treatment facilities at its existing premise, or building of new treatment facilities, increasing manpower and other resources. If the contractor also provides transportation services, the size of the fleet and transportation frequencies should be included in this review.

3.12.9. The personnel of the contractor should be trained regularly so that they are able to:

a. Recognise the different symbols and colour codes of medical wastes

b. Understand the hazards of the medical wastes being handled and take necessary precautions

c. Load and unload wastes safely

d. Understand how to operate the treatment methods utilized on their premise

e. Fill up the consignment notes and implement distribution of the copies correctly.

f. Execute the ERP and CP in the event of an untoward incident such as road accident, spillage etc.

3.13. Compliance by Contractors

All contractors issued a permit to provide transportation and treatment and disposal services shall comply with the requirements of the PHCWM, this guideline and other relevant legislations.

4. Technical Guidelines and Specifications

This chapter will describe the technical specifications for the following:

a. Temporary storage area for healthcare waste
b. Encapsulation
c. Secured landfill
d. Incineration

4.1. Temporary Storage Area for Health Care Wastes

4.1.1. A temporary storage area may be defined as a central healthcare waste store (CHWS), which is to be used to temporarily store healthcare wastes before it is treated on-site or before it is transported out to an off-site treatment or disposal facility. It may also be called a central healthcare waste store to distinguish it from satellite accumulation points which are areas within the wards and departments where waste is first generated.

4.1.2. A central healthcare waste store (CHWS) is necessary for better management and control of healthcare wastes and to ensure that the correct waste categories are diverted to the correct treatment facility. Hence the activities that need to be undertaken at a CHWS are:

a. Weighing and documentation of the weight of the various waste categories.
b. Diverting of relevant wastes to on-site treatment facilities.
c. Packaging of wastes for transport out to off-site treatment or disposal facilities.
d. Recording of consignment notes for the wastes transported out to an off-site treatment facility.

4.1.3. The factors to be considered in designing and constructing a CHWS are:

a. The amount of waste generated by categories.
b. The wastes categories that will be treated on-site and/or off-site.
c. On-site treatment operations:
    - It may not be economical for a treatment facility to operate daily if the waste generation is small. Hence wastes may need to be accumulated for a number of days before it is treated.
    - Estimated down-time for maintenance each week/month.
d. The transportation of wastes to an off-site treatment facility:
    - Who is the transporter(s) approved to collect waste from the HCE?
    - What categories of wastes is the transporter(s) permitted to carry?

- What is the capacity of the vehicle(s)?
- How often can the transporter(s) come to the HCE?
- How reliable is the transportation services?
- If only one transporter is licensed, is the transporter permitted to carry the different categories of wastes in the same vehicle?

e. The transportation route between the HCE and the off-site treatment facility:

- What is the accessibility of the route in terms of the type and size of the vehicle that can access the route?
- Is the route prone to flooding or other problems that would delay the arrival of the vehicle?

f. Projected growth rate of waste generation.

g. Site selection:

- The general waste and medical waste stores may be in the same location within the HCE premise as long as there is a clear separation between these two storage areas. Aesthetically it would be better to have the storage areas at one location than at two different locations.
- The CHWS should be located in close proximity to on-site treatment facilities.
- The CHWS should preferably be away and out of sight of patient areas, patient traffic, and cooking areas.
- The CHWS should be easily accessible to the transport vehicles if the wastes are to be transported out to treatment or disposal facilities. The access road should have appropriate load bearing capacity for these vehicles.
- The CHWS should be located in an area that has good ventilation.
- The CHWS should be located in an area that is not subject to flooding. If the entire HCE premise is subject to flooding then the CHWS will need either to be elevated or have barriers to prevent flooding of the CHWS.

4.1.4. General specifications for a store are:

a. The CHWS may be a constructed building with different rooms allocated for different waste categories or it may be in the form of commercially available portable units.

b. The CHWS should be covered so that the wastes and equipments are not exposed to sun and rain.

c. Nevertheless adequate ventilation needs to be provided. This can be done by leaving some space between the top of the wall and the ceiling or by using ventilation bricks or louvers on the sides of the walls.

d. Good lighting should be provided.

e. Designated areas/rooms should be allocated for the different categories of waste generated at the HCE. These areas/rooms should be marked with the required symbols and warning signs.

f. There should be an area for weighing and documentation to be carried out.

g. The CHWS must have sufficient capacity, with space for collection trolleys filled with waste and space for storage of clean collection trolleys.

h. There should be separation between filled trolleys and clean and empty trolleys.

i. There should be an area for washing and drying of collection trolleys.

j. There should be an area for cleaning the vehicles, if the vehicles belong to the HCE.

k. These areas should be marked for its designated use, e.g. *Area for Clean Trolleys*, *Bin Washing Area, Filled Trolley Area* etc.

l. If the hospital has an incinerator or any other treatment facility, the waste storage room should be located near it.

h. An access path for collectors and collection trolleys should be provided as follows:

- The path connecting the CHWS to the various points of waste generation within an HCE and to the on-site treatment facility (if any) should be smooth so that the containers can be easily and safely wheeled between these points:
    - Without the possibility of collection trolleys toppling over and spillage occurring.
    - Without causing undue strain on the collectors and possible injury to them.
- The gradient should not be steep causing difficulties in pushing the collection trolleys or in preventing it from rolling downwards.
- The path should be made of materials that are not slippery.

m. The walls and floors of the CHWS should be smooth, of impervious material and easy to clean. The floors should have the necessary gradient for good drainage.

n. The windows and ceiling should be covered with a net to prevent entry of insects and animals.

o. The in and out doors should be large enough for collection trolleys, and possibly lifting devices.

p. Adequate facilities such as water supply, protective gear, and equipment for cleaning and disinfecting the floor should be available.

q. It has a cold room for keeping degradable wastes.

r. If the store is elevated there should be a ramp for easy maneuvering of filled collection trolleys into the designated areas.

s. Hand washing facilities should be provided, complete with disinfectant soap and paper towels.

t. The CHWS should be equipped with electricity and water.

4.1.5. Special considerations for infectious and pathological waste stores:

a. If infectious and pathological wastes are to be stored for more than 24 hours, refrigeration should be provided and this should be maintained at below 6^{o}C.

b. Even if waste is transported out daily to an off-site treatment facility, additional capacity equivalent to one day's generation of waste should be provided as a contingency measure. Additional capacity would be required if transportation is less frequent.

c. The wastes should be contained, e.g. in enclosed bins to prevent possible leakage from the waste bags and contamination of the area.

4.1.6. Special considerations for chemical and pharmaceutical waste stores:

a. Incompatible wastes should not be stored near each other. In general the incompatible waste groups are as follows:

- Acids and bases.
- Organics and acids.
- Cyanide, sulfide or arsenic compounds and acids.
- Alkali or alkali earth metals, alkyl lithiums etc. and aqueous waste.
- Powdered or reactive metals and combustible materials.
- Mercury or silver and ammonium containing compounds.

b. The results could be disastrous if an accidental release of incompatible wastes occurred. To prevent this from happening, the containers of wastes should be stored in secondary containment areas.

c. It is often the case in an HCE laboratory that several chemicals, based on the testing protocol, are mixed when carrying out diagnostic tests. These mixtures should also be stored in a separate secondary containment area from the waste groups above.

d. A secondary containment area:

- Generally consists of a concrete floor with a berm or dike to contain the spillage and prevent the flow of the waste into another area and mixing with incompatible wastes.
- The floor must be free of cracks or gaps and must be impervious.

- Materials used for the floor should be able to withstand normal loading and physical damage caused by container handling.
- For areas where liquid wastes will be stored, the area should be designed such that it can contain the contents of the largest container to be stored in the area or 20% of the total quantity of the waste to be stored, whichever is the greater.
- To maximize utilization of space, stacking of containers is permitted provided that:
    - The enclosure walls or partitions between incompatible waste areas are sufficiently high and made of impermeable material.
    - The containers can be made secure to prevent toppling.
    - The containers are stacked in an upright position and these containers can be easily and safely moved.
- For smaller containers racks may be constructed but the materials must be compatible with the wastes to be stored on these racks and must be strong enough to carry the full weight of the wastes. A sill and drip tray to contain and collect spillage or leakage must be provided.
- In the case of small waste producers, cabinets with racks may be considered but these must also be constructed with materials compatible with the wastes to be stored. These cabinets must have a sill and drip tray to contain and collect spillage and leakage and must have ventilation holes.
- Floor drains around these areas should be plugged.
- There must be enough space to position pallets of container with enough space between them to allow workers to easily inspect containers and to handle them. Where large containers or drums are used, there should be sufficient space for a lifting device to maneuver.

e. Notwithstanding the provision of secondary containment areas, the containers of wastes should preferably be elevated on pallets to avoid contact with standing water or spillage.

4.1.7. Genotoxic waste: Storage areas for these should be separate from other waste areas. The specifications described above for chemical and pharmaceutical waste storage areas may be applied.

4.1.8. Radioactive wastes:

a. It is recommended that radioactive wastes are not stored at the CHWS. It should be stored close to the point of generation where protective lead containers are more readily available and where radioactivity levels may be measured.

b. For low-level infectious radioactive wastes these may be stored with infectious wastes after these have decayed to safe levels.

4.1.9. Pressurized containers:

a. It is recommended that pressurized containers are not stored at the CHWS. It should be stored close to the point of use so that gas suppliers may more readily collect them when delivering fresh supplies.

b. However these empty containers should stored separately and clearly indicated as empty containers.

c. A chain or some other device to secure the containers and prevent toppling should be provided.

4.1.10. General waste:

a. If it is the policy of the HCE to segregate the general waste into organic waste and recyclables, then separate storage areas should be provided for this.

b. The separation of these areas is not as stringent as for the medical waste store. Basically it is to ensure that recyclable items do not get unduly soiled and are aesthetically acceptable.

c. To minimize the amount of space required, segregation should be done at source to avoid the need for sorting at the CHWS.

d. Racks should be provided for recyclable materials such as paper and carton boxes to prevent damage from standing water.

4.1.11. Security

a. The entire CHWS should be fenced and equipped with a lock.

b. The individual storage rooms or portable cabins should also be equipped with locks.

c. Warning signs should be posted at visible areas of the CHWS and these should be readable from 50 feet away.

d. The signs should indicate:

- The nature of wastes stored on site, i.e. infectious, hazardous etc.
- That access is only permitted by authorized personnel; others should keep out of the area.
- That no smoking or open flame is allowed within 50 feet of the area.
- That the use of PPE is required before entering the area.

4.1.12. Wash area for collection trolleys:

a. The area for washing and drying of collection trolleys should be well ventilated to prevent build-up of moisture and fungal growth.

b. The wash area should be connected to the sewer, if available, or a septic tank.

c. The washing area should be constructed with a slight gradient so that water flows into the drain hole that leads into the sewer or septic tank.

d. The necessary detergents, disinfectants, washing pads and PPE should be available for safe and effective cleaning to be done.

4.1.13. Safety and Hygiene Requirements:

a. Spill kits should be provided and this should include absorbents / adsorbents, disinfectants, buckets, shovel, torch, disposable container, and plastic waste bags with appropriate labels. These should be placed where they are easily accessible and visible. Different spillage kits for different purposes should be marked.

b. Select fire extinguishers that are compatible with the types of potential fire hazards present and place them so they are visible from the front entrance. The types of fire extinguishers and purpose, extracted from the Australian Standard, are shown in **Appendix 3**. The fire extinguishers should also be easily accessible and not blocked by equipments, furniture, wastes etc.

c. Eyewash and deluge showers should be provided and these should be located within easy access.

d. Some means of communication should be provided. This could be a telephone or a two-way radio.

e. Pest control measures should be incorporated to prevent entry of insects, rodents and other pests.

f. Appropriate PPE should also be provided.

g. The relevant Material Safety Data Sheets (MSDS) of chemical wastes stored should be available as a guide on precautionary measures required.

4.2. Encapsulation

4.2.1. The process of encapsulation is the process of enclosing as in a capsule.

4.2.2. The objective of this process is to physically immobilize the waste, make the waste not apparent, prevent contact with leaching agents such as water and isolate the waste from humans, animals and the environment.

4.2.3. There are two forms of encapsulation:

a. Micro-encapsulation, where the waste is treated or coated with sealing agents to lock up the contaminants in the structure of the waste and prevent chemical interaction with the environment. This is done before solidification occurs.

b. Macro-encapsulation, which involves placing the waste in a steel or plastic drum and filling up the drum with pozzolanic, flowable material that fills up the remaining space, solidifies and forms an enduring barrier with the environment.

Sometimes these two processes are combined.

4.2.4. The form that is more relevant to healthcare waste, easier to achieve and discussed in this section is macro-encapsulation. This pre-treatment may be used if no other treatment options are available for:

a. Pharmaceutical waste

b. Sharps waste

c. Small quantities of chemical waste

d. Small quantities of genotoxic waste

4.2.5. Encapsulation is a form of pre-treatment only, to render the waste safer for storage or landfilling. Thus the factors to be considered when deciding on encapsulation are:

a. The categories of waste generated and whether encapsulation is suitable.

b. The amount of waste generated.

c. The availability of land within the HCE if the encapsulated waste is to be buried on-site.

d. If the encapsulated waste is to be transported out to a landfill:

- Who is the transporter approved to collect the encapsulated waste from the HCE?
- What is the capacity of the vehicle?
- How often can the transporter come to the HCE?
- How reliable is the transportation service?
- Is there adequate space for storage of the encapsulated waste until the transporter arrives?

e. Space for encapsulation work to be undertaken. Prior to encapsulation, temporary storage space is also required. The specification for this is described in section 4.1.

f. If there are available suppliers of:

- Encapsulation material, which must be non-degradable. Options are cement, lime mortar, plastic foam or bituminous sand. Fly ash and cement kiln dust may also be used for encapsulation.
- Drums for encapsulation.
- The suppliers of both the encapsulation materials and drums must also be reliable.

g. Projected growth rate of waste generation for the waste categories to be encapsulated.

4.2.6. Applicable methods of encapsulation are:

a. The simplest method involves digging a pit into which the waste is discarded and then filled with encapsulation material.

- However the location of such a pit must take into consideration the amount of waste generated, the type of soil and distance to groundwater.
- The pit should be about 2 – 3 m deep and approximately 2 m wide.
- If possible the entire pit should be constructed of cement or some other impermeable material. If this is not possible, the pit should be lined with 30 cm of impermeable material such as compacted clay or flexible impermeable membrane.
- The top portion of the pit should be slightly elevated and sloped to prevent surface water from entering the pit. The pit should also be covered with a hinged and lockable lid.
- The pit area should be fenced off to prevent entry of animals and unauthorized persons.
- Once the pit is filled with about 90% of waste, the encapsulation material should be poured in to completely enclose the entire mass of waste. The following proportions should be used:
  - 15% cement
  - 15% lime
  - 60% sand
  - 10% water
- Once the pit is full, the pit should be sealed with soil or cement and the area clearly identified.
- Such a pit is suitable for remote HCEs where sharp waste generation is low. Nevertheless it is preferable that sharps are discarded into sharps containers before they are placed into the pit.

b. Alternatively, wastes may be placed into a steel or HDPE drum until it is 90% filled. The remaining space is then filled with the encapsulation material, sealed and disposed in a landfill. This would be preferable to the use of a pit.

c. In the case of genotoxic waste,

- A ratio of 40% cement, 30% water and 30% waste by weight should be used.
- The mixture should be well mixed and allowed to set and should be sealed before disposing into a landfill.

d. An alternative for pharmaceuticals is:

- Removing pharmaceuticals from the packaging material and grinding the pharmaceuticals with a mix of water, cement and lime to form a homogenous paste.
- This is then transported in the liquid state by a concrete mixer truck and decanted into a landfill where it will set into a hard harmless substance.
- The approximate ratios are:
  - Pharmaceutical waste - 65%
  - Lime - 15%
  - Cement - 15%
  - Water - 5%

e. A commercially available device that:

- Consists of a computerized sterilization unit, disposal metal canisters and treatment with dry heat. This device may be used to treat sharps and infectious wastes and is useful for small HCEs.
- The filled canister will then be heated to a temperature of between 165 – 185^{o}C for two and a half hours.
- The heating process within the device sterilizes the waste, renders sharps unrecognizable and unusable, and seals the canister, thus encapsulating the waste.
- The canister can then be safely disposed at a landfill.
- The device comes with an optional add-on that can compact the canister, thus reducing storage and landfill space required.

f. Alternatively encapsulation material may be poured directly into sharps containers that have been filled with sharps. Once the encapsulation material has dried and hardened the sharps container may be disposed at a landfill.

g. Encapsulation of mercury waste using paraffin wax:

- This is best done at the point of generation.

- In a glass jar pour in some molten paraffin wax and ensure the bottom of the jar and all other surfaces are coated with the wax. Allow the wax to harden.
- Wastes containing mercury can then be discarded into the jar.
- As the jar is filled with waste, periodically pour in additional molten paraffin wax to coat the contents and fill the spaces.
- When the jar is full, pour in more molten wax to ensure all spaces are filled and the contents are immovable.
- Screw the cap on the jar and coat the outer surface with several layers of molten paraffin wax, allowing each layer to harden before applying the next layer.
- Obtain a heavy pail that is large enough to contain the jar with about 50 mm space around the jar.
- Coat the bottom of the bucket with about 50 mm of the molten paraffin wax.
- After the wax has almost hardened, place the jar into the bucket and pour in additional wax until the level of the wax fills a third of the bucket.
- Allow this to almost harden and then pour in additional wax again. Repeat the process until the jar is completely encased in the paraffin wax.
- When the jar is completely encased and the bucket is filled, put the lid on. The type of bucket that requires the lid to be hammered into place is the most ideal.

4.2.7. Sharps and pharmaceutical wastes may be mixed together in the same capsule.

4.2.8. When encapsulating chemical wastes, incompatibility characteristics must be considered as discussed in section 3.4.4.

4.2.9. The specification for the CHWS, as described in section 4.1 is applicable to the encapsulation processing area. Hence it would make economical sense for the encapsulation processing area to be housed within the CHWS area. Additional requirements are:

a. Adequate space should be provided for:

- The encapsulating material. The area should be elevated to keep the material dry and the materials stored on pallets or shelves.
- Drums. Space should be provided for filled drums and empty drums. The space for filled drums should also be separated into areas for drums that are still setting and those which are ready to be transported out to landfills.
- Mixing of the encapsulation materials with the waste.

b. Equipments required:

- A mixer.
- A lifting or hoisting device.

4.2.10. The specification described above is for on-site encapsulation. New encapsulation formulations are being developed and larger scale encapsulation facilities have also been used in some countries for mercury contaminated waste and nuclear waste. The decision to set up a larger scale encapsulation facility should take the following into consideration:

a. For the facility to be economically viable and sustainable there must be sufficient volume of waste to be processed at the facility. Thus the facility may need to expand its scope beyond HCE origins.

b. The vendor and/or operator of the facility should be required to provide information, i.e. whether their proposed formulation(s):

- Has a proven record of success with supporting data on long-term effectiveness and durability of the encapsulated waste.
- Is compatible with the waste to be encapsulated. For example the sulphur polymer stabilization/solidification formulation is not compatible with strong alkaline solutions, strong oxidising solvents, aromatic or chlorinated solvents.
- Can be used for different forms of waste, i.e. solids, liquids and sludges.
- Has a high waste loading. Higher waste loading would minimize landfill space required.
- Requires additional heat input. If required this may increase the cost of treatment.
- Requires chemical fixation to stabilize the hazardous components of the waste.
- Results in the generation of secondary wastes. This would increase loading into landfills or require additional treatment.
- Generates potentially hazardous off-gases or there is a possibility of ignition and explosion. If so engineering controls would need to be incorporated.
- Results in a final encapsulated block that:
    - Has a high degree of water tightness and chemical resistance.
    - Is not prone to cratering, cracking or excessive shrinking.

c. The vendor and/or operator of the facility should also be required to:

- Provide a description of supporting infrastructure that will be provided in the package. These should include temporary waste stores, stores for encapsulated waste, weighbridge, control panels, administrative and site control office etc.
- Provide a description of the maintenance that will be carried out and a guarantee on a minimum uptime of the facility.
- Provide written assurance that spare parts are available and that obsolescence of critical components of encapsulation facility will not be an issue.
- Provide written assurance of after-sales service if the vendor is merely engaged to supply, construct and install the encapsulation facility. A written contract for this should be considered.
- Undertake an EIA as may be required by the Ministry of Environment and the Sub-Decree on Environmental Impact Assessment.
- Develop written standard operating procedures (SOP) and an operating and maintenance manual. This should include waste handling, operation of the plant, setting times etc. as well as safety and health precautions.
- Provide assurance that all personnel are trained and are well versed on how to operate the encapsulation facility to ensure compliance with standards and to ensure safety. If possible a certification programme should be instituted.
- Identify key performance indicators on their operations and services.
- Provide training for hospital or Ministry of Health staff on these indicators.
- Provide a description of the transportation fleet if it is a regional facility and it is considered a requirement that the operator of the facility provide this service.
- Develop emergency response and contingency plans and thereafter train all personnel on these measures.

d. The contractor engaged to design the facility should have the pre-requisite experience and knowledge in the design and operation of such a facility. The facility should also be designed with simplicity in mind to minimize possibility of failure and error. Some critical features are:

- There should be a linear progression of activities from receipt of waste, to stations for pouring of encapsulation materials, setting areas, drum inspection area, etc.
- If different types of wastes are received at the facility and different formulations need to be employed, then the different process lines need to be clearly marked.
- Conveyor belts should be considered to minimize the handling of drums.

- Control and instrumentation should be simple. For example interlocks should be mechanical or hard-wired.
- All mechanical components should be durable to prevent down-time and motors of conveyor belts should be placed outside the processing area for easy access and maintenance.
- To prevent splashing, the flow rate of the encapsulation material should not be more than 10 litres / minute. Physical barriers should also be incorporated to prevent splashing.
- Engineering controls for ventilation and extraction of gases produced by the reaction between encapsulation materials and some wastes. For example hydrogen is produced when cement, which is highly alkaline, reacts with reactive metals such as aluminium and magnesium.

e. Supply of encapsulation material

- Naturally occurring materials such as cement and fly ash are prone to variability and these can affect the quality of the final product.
- To minimize the impact of such variability, these materials should be sourced from single source supplies and preferably those that can comply with national/international standards.
- Depending on the formulation used, additional requirements may need to be specified to the supplier to ensure the quality of the final product.
- Contracts established with suppliers should require notification of change in the properties so that the necessary changes in formulation can be done.

f. A reliable source of electricity supply should be available. If electricity supply is not reliable, a stand-by generator set may have to be considered to minimise disruption in operations.

g. A reliable source of water supply should be available. If the water supply is not reliable, a water storage tank or a well may have to be considered to minimise disruption in operations.

h. The total area of the encapsulation facility. The land area for the total encapsulation facility will need to accommodate the following:

- Site entrance and control point
- Weighbridge
- Administrative and site control office
- Waste inspection and temporary storage area
- Stores for treated waste
- Water supply
- Lighting

- Vehicle cleaning facility and parking area (if the vehicle fleet belongs to the incinerator operator)
- Stand-by generator
- Water storage tank
- Fire fighting equipment
- Fencing and signage

i. Access to the plant:

- Transportation services from the relevant HCEs to the encapsulation plant must be available. If not the encapsulation plant operator may consider having its own fleet to provide the service.
- The plant should be accessible and the routes to the plant from the different HCEs it serves should not be prone to flooding, landslips etc. The access roads should also have appropriate load bearing capacities.

j. Standardisation of waste receipt:

- It might be prudent for the contractor to supply standard drums to waste generators so that waste received at the facility are ready to be put onto the process line after weighing and inspection.
- Alternatively standard specifications of drums to be purchased and used by waste generators may be provided by the facility.
- This would minimize the need to transfer waste into appropriate drums for processing and minimize the need for disposal of the original containers.

k. Safety and Hygiene Requirements:

- Spill kits should include absorbents / adsorbents, disinfectants, buckets, shovel, torch, disposable container, and plastic waste bags with appropriate labelling. These should be placed where they are easily accessible and visible. Different spillage kits for different purposes should be marked.
- Select fire extinguishers that are compatible with the types of potential fire hazards present and place them so they are visible from the front entrance and are not blocked by other equipments and/or furniture. See **Appendix 3**.
- Eyewash and deluge showers should be provided and these should be located within easy access.
- Some means of communication should be provided. This could be telephone or a two-way radio.
- Appropriate PPE should also be provided.
- Chemical safety data sheets (CSDS) for chemicals used as well as wastes handled should be available so that personnel are aware of the chemical properties and the safety requirements relating to these chemicals.

l. Management of the facility

- Carry out periodic maintenance in accordance with the maintenance programme to replace or repair defective components. This should include maintenance of spare parts inventory, record keeping etc.
- Staff should be periodically re-trained on all aspects of the operations of the facility as well as safety, ERP and CP requirements.
- Develop performance indicators and carry out monitoring and analysis of these indicators.
- Regularly submit reports to relevant agencies on their compliance with these key performance indicators and compliance with relevant regulatory requirements.

4.3. Secure Landfill

4.3.1. Basically a landfill is a site where waste can be buried in a manner that ensures safe containment and degradation of waste over time. For hazardous waste disposal, an engineered landfill or secure landfill is required.

4.3.2. Secure landfills are designed with protective measures against pollution of groundwater, surface water and air including control of dust, wind-blown litter, bad odour, fire hazard, bird menace, pests or rodents, greenhouse gas emissions, slope instability, and erosion. The objective is normally for a filled and closed landfill to be put back into some form of productive use such as parks.

4.3.3. The construction of a secure landfill involves capital investment as opposed to an open dumpsite. Thus for a secure landfill to meet its objectives, segregation has to be effective otherwise the landfill will quickly fill up.

4.3.4. The design life of the landfill:

a. This consists of the active phase, closure and post-closure phase.

b. The active phase of a landfill is the period when waste filling is still carried out. Depending on size of the land identified, it can range from 10 – 25 years.

c. The closure and post-close phase is when the active phase is over and the landfill is closed and monitored. The norm for this phase is 30 years.

4.3.5. The factors to be considered in designing and constructing a secure landfill are:

a. Waste Type: The wastes categories that will be landfilled. Incompatible wastes will have to be placed in separate units or cells.

b. Waste Volume: The amount of waste to be landfilled and projected growth rate of waste generation.

c. In addition to the factors above, computation of the capacity of the landfill has to take into account the volume occupied by the liner material, intermediate cover and final cover material. This will determine the height of the landfill.

d. The total area of the landfill facility. An additional 15 – 30% of the actual landfill site may be needed to accommodate infrastructure and support facilities and to create a buffer zone around the site. The infrastructure and support facilities include the following:

- Access roads
- Site entrance and control point
- Weighbridge
- Administrative and site control office
- Waste inspection and temporary storage area
- Sampling and testing facility (if located on-site)
- Equipment workshops and garages
- Water supply
- Lighting
- Vehicle cleaning facility & parking area (if the vehicle fleet belongs to the incinerator operator)
- Surface water draining facilities
- Leachate management facility (may include an on-site treatment facility)
- Gas management facility
- Monitoring wells
- Fire fighting equipment
- Signs and directions
- Fencing and buffer zone/green belt area

e. Identifying the site for a landfill should take the following into consideration:

- Landfills should not be sited near ponds, lakes, rivers wetlands, flood plains, highways, habitation, critical habitat areas, water supply wells, airports, or the coast.
- Local zoning requirements will need to be checked. In the absence of local zoning requirements, the following can serve as a guide:
    - No landfill should be constructed within 200 m of any or pond.
    - No landfill should be constructed within 100 m of a navigable river or stream.

- No landfill should be constructed within a flood plain.
- No landfill should be constructed within 500 m of a water supply well.
- No landfill should be constructed within critical habitat areas and forest reserves.
- No landfill should be constructed within 500 m of a habitated area.
- No landfill should be constructed within 500 m of a public park.
- No landfill should be constructed within 500 m of the right of way of any state or national highway.
- No landfill should be constructed within a zone around airports as stipulated by the aviation or other relevant authorities.
- No landfill should be sited in a coastal zone.

4.3.6. Depending on the topography of the site, water table and availability of cover material, the landfill may take the form of:

- Above ground landfill –flat undulating areas
- Below ground landfill – low lying areas, depressions or pits
- Slope and valley landfills – hilly areas

4.3.7. The contractor engaged to design, construct and operate the landfill facility should have the pre-requisite experience and knowledge in the design and operation of such a facility and should incorporate the following essential elements:

a. A liner system at the base and sides to prevent migration of leachate or landfill gas to the surrounding environment. The membrane that has found to be durable and commonly used in landfills is high density polyethylene (HDPE) membrane. Additionally there should be a layer of clay, and or gravel supporting this membrane.

b. A leachate collection and treatment facility to collect and extract leachate from within and from the base of the landfill and then treating the leachate to meet standards.

c. A landfill gas collection and control facility to extract gas from within and from the top of the landfill.

d. A surface water drainage system which collects and removes all surface runoff from the landfill site.

e. Wind dispersal control system.

f. Leak detection system.

g. A fenced buffer zone and green belt around the landfill facility to serve as a visual and protective barrier.

h. An environmental monitoring system to collect air, surface water, and ground water samples around the landfill site for analysis.

i. A weighbridge and documentation area.

j. A closure and post-closure plan which lists the steps that must be taken to close and secure the landfill site once the landfill is full. This should include a final cover system at the top to prevent infiltration of water and to support surface vegetation as well as long-term monitoring and maintenance of the closed landfill.

k. Safety provisions and basic amenities (for example, roads, lighting arrangements, water supply, protective gear, toilets).

f. The operating methodology needs to be worked out. A well-managed landfill is operated in phases so there is a progressive systematic use of the landfill area, such that at any given time there is an area that is actively being filled, a part being prepared to receive waste, a part that is undisturbed and with time a part that has a final cover.

g. The liner material selected should:

- Provide adequate stability at the base of the landfill
- Provide adequate stability along the sides/slopes of the landfill
- Be of adequate strength to withstand construction / vehicle / waste loads
- Be impermeable and compatible with the waste to be landfilled and the leachate generated

h. The availability of material for intermediate and final cover.

i. Leachate collection and treatment:

- An estimate of the quantity of leachate needs to be undertaken to design the leachate drainage, collection and removal facility.
- The material used for the leachate system should be able to withstand the effects of the leachate.
- Leachate treatment:
    - A decision has to be made whether leachate will be treated on-site or off-site.
    - If on-site, then a treatment facility has to be installed with space allocation made for this.
    - If off-site, space will still be required for storage and pre-treatment. A treatment facility and transportation service will also have to be available.

j. Gas emission management can take the form of:
   - Controlled passive venting
   - Collection for treatment

k. Base and slope stability:
   - The stability of the base needs to be checked for load bearing failure and excessive settlement.
   - The stability of the slope needs to be checked and this includes checking the liner system at the excavated slope. In the case of above ground landfills, the temporary slopes as the waste is landfilled need to be checked.
   - The stability of the above ground portion of completed landfills and the stability of the cover.

l. Site entrance:
   - This should be a permanent structure with separate entrance and exit lanes and gates.
   - The gates should be controlled and manned and therefore a guardhouse is required.
   - There should be sufficient parking space to prevent a queue of vehicles spilling into the main road or highway.
   - Lighting and directions at the entrance gate.
   - Weighbridges to weigh loaded vehicles and unloaded vehicles to obtain accurate data on waste inputs into the landfill.

4.3.8. The cover system should achieve the following:

a. Prevent infiltration of precipitation into the landfill

b. Drain away water to prevent accumulation on the cover

c. Minimise erosion of the cover

d. Maintain the integrity of the cover

e. Function with minimum maintenance for the post closure period.

4.3.9. The vendor and/or operator of the facility should also be required to:

a. Provide a description of supporting infrastructure that will be provided in the package. These should include temporary waste stores, weighbridge, administrative and site control office etc.

b. Undertake an EIA as may be required by the Ministry of Environment and the Sub-Decree on Environmental Impact Assessment.

c. Develop written standard operating procedures (SOP) and this should include waste handling as well as safety and health precautions.

d. Provide assurance that all personnel are trained and are well versed on how to operate the landfill facility to ensure compliance with standards and to ensure safety. If possible a certification programme should be instituted.

e. Identify key performance indicators on their operations and services.

f. Provide training for hospital or Ministry of Health staff on these indicators.

g. Provide a description of the transportation fleet if it is a regional facility and it is considered a requirement that the operator of the facility provide this service.

h. Develop emergency response and contingency plans and thereafter train all personnel on these measures.

4.3.10. Aesthetics:

a. Structures should be finished in natural colour and screened with vegetation so as to blend in with the landscape.

b. Site should be kept clean and tidy with equipment stored out of view.

c. Soil removed should be stockpiled parallel to the transport route so as to further reduce visibility of the site.

d. Re-vegetation selected for closure is appropriate to the local species.

e. Noise abatement measures may be needed at the periphery of the landfill to prevent nuisance to the local community.

f. Dust may be a problem during dry season while the site is being prepared or constructed. This should be avoided by spraying roads with water.

4.3.11. Safety and Hygiene Requirements:

a. Spill kits should include absorbents / adsorbents, disinfectants, buckets, shovel, torch, disposable container, and plastic waste bags with appropriate labelling. These should be placed where they are easily accessible and visible. Different spillage kits for different purposes should be marked.

b. Select fire extinguishers that are compatible with the types of potential fire hazards present and place them so they are visible from the front entrance and are not blocked by other equipments or furniture. See **Appendix 3**.

c. Eyewash and deluge showers should be provided and these should be located within easy access.

d. Some means of communication should be provided. This could be telephone or two-way radio.

e. Appropriate PPE should also be provided.

f. Chemical safety data sheets (CSDS) for chemicals used as well as wastes handled should be available so that personnel are aware of the chemical properties and the safety requirements relating to these chemicals.

4.3.12. Management

a. Staff should be periodically re-trained on all aspects of the operations of the facility as well as safety, ERP and CP requirements.

b. Develop performance indicators and carry out monitoring and analysis of these indicators.

c. Regularly submit reports to relevant agencies on their compliance with these key performance indicators and compliance with relevant regulatory requirements.

4.3.13. Factors to consider in deciding on an HCE-specific or regional landfill:

a. An HCE-specific landfill is one that is sited within the HCE premise and used only for the disposal of wastes generated in that HCE.

b. A regional landfill is one that is not sited within the HCE premise and serves as a disposal site for wastes generated from several HCEs. Opening up the landfill facility to other hazardous waste generators should be considered to make it more economically viable for the operator.

c. Open dumping or a poorly designed and constructed landfill can have adverse environmental health impacts, not to mention the huge cost of cleaning up the contaminated area thereafter. However the specifications for a secure landfill as outlined above would require substantial investment and identification of suitable sites for the construction of such a landfill. Hence the decision on type of landfill should take all these into consideration.

d. If the landfill is to be used as a regional landfill receiving waste from multiple HCEs, additional factors to be considered include:

- Whether transportation services from the relevant HCEs to the landfill site are available. If not the landfill operator may consider having its own fleet to provide the service.
- The accessibility of the route from the HCEs to the landfill site. The access roads should also have appropriate load bearing capacities and should not be prone to floods, landslips etc.

4.4. Incineration

4.4.1. Incineration is the controlled burning of solid, liquid or gaseous combustible wastes. Combustion of wastes results in the formation of ash and gases.

4.4.2. Incineration has the advantages of waste volume reduction by 90 – 95% thus reducing significantly the volume of waste to be landfilled. It can also be adapted for the destruction of a wide variety of wastes, sterilizes infectious waste, and renders the waste unrecognisable.

4.4.3. The down side of incineration is that residues are produced which contain harmful pollutants, which if not handled properly can contaminate the air, soil and water resulting in adverse health consequences. The 3 main residues produced are:

a. Air pollutants

- Since healthcare waste is a heterogeneous mix, the pollutants generated include particulate matter, sulphur oxides, nitrogen oxides, volatile organic compounds and carbon monoxide, as well as dioxins and furans, arsenic, lead, cadmium, chromium, mercury, and hydrochloric acid.
- These air emissions can have both direct and indirect health impacts.
- Direct impacts are through inhalation by workers and the local community around the incinerator plant.
- Indirect impacts are through ingestion of food and water contaminated by the pollutants or through dermal contact and absorption with contaminated dusts, air and water.
- The greatest concern is the emission of air pollutants and in particular the group of pollutants known as dioxins and furans.
- The term “dioxin” is commonly used to refer to a family of toxic chemicals that all share a similar chemical structure and a common mechanism of toxic action. This family includes seven of the polychlorinated dibenzo dioxins (PCDDs), ten of the polychlorinated dibenzo furans (PCDFs) and twelve of the polychlorinated biphenyls (PCBs).
- The most toxic compound is 2,3,7,8-tetrachlorodibenzo-p-dioxin or TCDD and this has been confirmed as a cancer hazard to people by the USEPA and International Agency for Research on Cancer (IARC).
- In addition to cancer, dioxin exposure can also cause severe reproductive and developmental problems, damage the immune system and interfere with hormonal systems and has been linked to birth defects, decreased fertility, learning disabilities, lung problems, skin disorders and much more.

b. Solid residues

- Bottom ash, the end-product after combustion of the waste
- Fly ash, produced from air pollution control and treatment

c. Liquid residues

- Liquid residues are produced from air pollution control and treatment

4.4.4. Notwithstanding the above concerns, incineration is a better option than open dumping or uncontrolled burning of waste. However the design, construction and operation of the incinerator will have to take these concerns into consideration to minimize the deleterious effects of the residues. The essential components of an incinerator plant that are required to achieve this are:

a. Primary combustion chamber (PCC) which brings about destruction of waste through the following process:

- Drying as a consequence of the heating process
- Volatilization of vapours and gases
- The burn-down of burnable solids left after volatilization.

b. Secondary combustion chamber (SCC) which brings about destruction of all the unburned gases, vapours, and particulates released from the primary combustion process.

4.4.5. Air pollution control (APC) system may need to be incorporated and this may have chemical treatment combined with wet scrubbers or dry scrubbers. For incinerators with smaller waste loads this may not be required if it can be demonstrated that the quality of air emissions comply with the stipulated standards.

4.4.6. The 3 main types of incinerators that may be used for healthcare waste incineration are:

a. Controlled air incinerators

- This is sometimes called starved air incinerator and incineration is achieved with less than the stoichiometric amount of air required for combustion.
- This takes place in the PCC where the low air-to-fuel ratio dries and facilitates volatilization of the waste and burns most of the residual carbon in the ash. The required temperature in this chamber is relatively low (760 to 980°C).
- In the SCC, excess air is introduced. Additional heat may be required depending on the heating value and moisture content of the waste. Auxiliary burners located at the entrance of the SCC provide this additional heat when required. This will bring about the destruction of volatile gases. The required temperature in this chamber is higher (980 to 1,095°C).
- Gases are then directed to the incinerator stack or the APC system.
- Waste feed and ash removal can be manual or automatic depending on the unit size and purchase option selected.
- These incinerators can be operated in batch or continuous mode.

- Continuous mode incinerators typically have mechanical waste feeding systems with automatic charging sequence incorporated to promote stable combustion conditions and approximate steady state operation

b. Excess air incinerators

- These are typically smaller units and may be referred to as retort incinerators. They are typically a compact cube with a series of internal chambers and baffles and are typically operated in batch mode and are typically used for pathological wastes.
- Incineration is achieved by first heating up the SCC to the required temperature which is typically 870 to 980°C.
- When the required temperature is achieved, the primary burner is ignited and the waste in the PCC is dried, ignited and combusted by both the primary burner and radiant heat from the chamber walls.
- The vaporised moisture and combustion and volatile gases will then pass into the SCC via a flame port which connects the two chambers. Secondary air is also introduced at this point. Additional heat may be required to achieve complete combustion and this is introduced via secondary burners, which normally shuts off when target temperatures are achieved.
- Gases are then directed to the incinerator stack or the APC system.
- Once the chamber cools, the ash is manually removed from the PCC and a new charge of waste can be added.

c. Rotary kiln incinerators

- As the name implies, this consists of a rotating kiln. This is slightly inclined for migration of waste materials from the feed end to the ash discharge end.
- The through-put of the waste is determined by the angle of inclination and rotation rate of the kiln.
- Both the PCC and SCC are lined with acid-resistant and heat withstanding refractory brick.
- Combustion air enters the PCC through a port and a burner is used to maintain combustion and to maintain required temperatures.
- The vaporised moisture and combustion and volatile gases will then pass into the SCC. Complete combustion of volatiles is achieved in the SCC with introduction of excess air and additional heat via secondary burners.
- Rotary kiln incinerators generally require an APC control system as there is greater turbulent motion of the waste, resulting in higher solid burn-out rates and particulate entrainment in the flue gas.

Schematic diagrams of these incinerators are re-produced from the USEPA report "Compilation of Air Pollution Emission Factors", 1995 and shown in **Appendix 4**.

There are many other types of incinerators such as fluidized bed, liquid injection and plasma arc. In view of the current scenario in Cambodia and the limited resources available, these may not be applicable and are therefore not described in this guideline. Additionally some of the other technologies, such as the fluidized bed and liquid injection incinerators are not commonly used for medical waste.

4.4.7. The installation of an incinerator that will effectively treat healthcare waste and minimise discharge of pollutants and deleterious health effects involves a substantial capital investment. Thus effective reduction and waste segregation is necessary to ensure that only the appropriate quantity and relevant categories of wastes are incinerated.

4.4.8. The contractor engaged to design, construct and operate the incinerator facility should have experience and knowledge in the design and operation of such a facility. Nevertheless the following key elements and factors should be taken into consideration.

a. The categories, quantities and characteristics of wastes to be incinerated.

- This will determine if air pollution controls are required. Wastes containing metals and plastics are of concern.
- Continuous mode may be required if larger volumes are to be incinerated.
- Wastes with higher moisture content and lower volatile content would need a smaller SCC as opposed to wastes with lower moisture content and higher volatile content.

b. Incinerator performance

- Healthcare wastes can vary in BTU content from as low as 1500 BTU to 20,000 BTU. Thus charging rates and procedures would need to be adjusted accordingly to ensure incinerator performance.
- The 3 T's of incineration for optimum performance, i.e.
  - Temperature –
    - The temperatures must be maintained at an optimal temperature to ensure combustion of waste and destruction of the volatile gases.
    - The temperature must also not be too high such that damage of the refractory will result.
    - The temperature will be dependent on the other design parameters of the incinerator, i.e. turbulence and residence time.

- Typically a minimum of 1000^{o}C is required at the SCC to ensure destruction of dioxins and furans. A higher temperature of 1100 or 1200^{o}C may be required if the incinerator accepts pharmaceutical, cytotoxic and chemical wastes.

o Turbulence

- Some degree of turbulence is necessary to achieve optimum mixing of air, volatiles and heat.
- However if gas velocities are too low or too high, then optimum mixing is not achieved. Thus control of combustion rate is required to achieve optimum mixing.

o Residence Time

- Combustion requires time and if the waste burns too fast, the gases are pushed through too quickly to achieve optimum performance. Controlling the rate of combustion is again necessary.
- A residence time of 1 – 2 seconds is usually required but this is again dependent on the other factors described above.

c. Incinerator performance monitoring. Several parameters influence the efficiency of incineration. These are temperature, negative pressure levels and oxygen levels. Thus instrumentation to measure these parameters are required. The essential ones are:

- Temperature sensors or thermocouples should be installed to monitor and ensure that required temperatures are reached inside both the PCC and SCC. These sensors should be protected from the burner flame and should be located near the exit (i.e. not ear the burner flame) of the chambers to prevent damage and to provide a representative temperature reading of the chamber.
- An audible and visual alarm should be installed to warn the operator when the SCC temperature drops below the required temperature. Preferably there should also be an interlocking mechanism so that waste cannot be charged into the incinerator when the SCC temperature drops below the required temperature.
- Pressure gauges to measure incinerator draft.
- Oxygen and carbon monoxide analysers.
- Opacity monitors .
- Any other instrument or measurement considered necessary to measure performance.

d. Exhaust stack

- The exhaust stack or chimney should extend above the general terrain and clear the highest point of the building around the incinerator.

- This should be determined through an environmental impact assessment.
- The stack should also be equipped with a sampling platform and port for sampling and testing of emissions.

e. Site location and infrastructure.

- The incinerator should be sited such that prevailing winds blow away from the community, residences and other sensitive areas.
- The incinerator should be sited in accordance with the topography and be compatible with the premises in the surrounding area.
- There should be weather protection over the incinerator, in particular the burners, control panels and de-ashing area.
- A reliable source of electricity supply should be available. If electricity supply is not reliable, a stand-by generator set may have to be considered to minimise disruption in operations.
- A reliable supply of fuel, which could be diesel or gas.
- A reliable source of water supply should be available. If the water supply is not reliable, a water storage tank or well may have to be considered to minimise disruption in operations.
- Temporary stores should be provided to store waste before these are incinerated. In the case of infectious and pathological wastes, cold stores should be provided. The stores should be sufficient to hold 3 days' volume of waste received for treatment at the facility in the event of a shut-down for maintenance or repairs.
- Since the residues from the incineration and air pollution treatment predominantly contain hazardous materials, the following need to be considered:
    - There should be a secure landfill within reasonable distance for the final disposal of these residues. If landfilling within the incinerator premise is permitted, then space allocation for this should be made and the specifications as outlined above for a landfill should be taken into consideration.
    - If landfilling within the incinerator premise is not permitted, then accessibility to a secure landfill is required. Transportation services for the transfer of residues to the landfill site would also be required. A consignment note system should also be implemented for the residues.
    - Stores have to be provided as well for the residues generated as a result of the incineration and/or air pollution treatment processes. The capacity of the store should be sufficient to cater for the amount of residues generated taking into consideration the frequency of transportation out to secured landfills.

- Access to the plant.
    - If the incinerator is an HCE-specific incinerator, located within the HCE premise, then it should be located near the CHWS.
    - If the incinerator is an off-site, regional facility, then access roads should have appropriate load bearing capacities.
    - If possible the routes to the plant from the different HCEs it serves should not be prone to flooding, landslips etc.

f. The total area of the incinerator facility. The land area for the total incinerator facility will need to accommodate not only the incinerator but also the APC if this is deemed required. However it would make sense to allocate the land for subsequent installation when standards are made more stringent in the future. In addition to the APC, space must be allocated for the following:

- Site entrance and control point
- Weighbridge
- Temporary stores for waste and residues
- Administrative and site control office
- Waste inspection and temporary storage area
- Stores / landfill areas for bottom and fly ash
- Water supply
- Vehicle cleaning facility (if the vehicle fleet belongs to the incinerator operator) and parking area
- Bin cleaning facility
- Water sump for collection of wastewater to be recycled or treated before discharge
- Stand-by generator
- Fire fighting equipment

4.4.9. The incineration of waste is considered a better option than open dumping. However a poorly designed and a poorly managed incinerator can also have negative environmental health impacts. Notwithstanding the decision between small HCE-specific or larger regional incinerators, the vendor and/or operator of the facility should:

a. Have a proven record of their experience in operating incineration facilities if the vendor is engaged to install, construct and operate the facility.

b. Have a proven record of the success of the proposed incinerator model in meeting the needs of their clients if the vendor is only engaged to install and construct the facility.

c. Be required to:

- Provide a description of the incineration process which should include waste categories that can be incinerated, operating temperatures, residence time, layout of plant, etc.
- Show evidence that their proposed incinerator is able to meet emission limits. If not an APC system should be included in the package.
- Provide a description of supporting infrastructure that will be provided in the package. These should include temporary waste stores, ash stores, weighbridge, control panels, administrative and site control office etc.
- Provide a description of the maintenance that will be carried out and a guarantee on a minimum uptime of the facility.
- Provide written assurance that spare parts are available and that obsolescence of critical components of incinerator model will not be an issue.
- Provide written assurance of after-sales service if the vendor is merely engaged to supply, construct and install the incinerator. A written contract for this should be considered.
- Develop written standard operating procedures (SOP) and an operating and maintenance manual. This should include waste handling, operation of the plant, emission levels etc. as well as safety and health precautions.
- Provide assurance that all personnel are trained and are well versed on how to operate the incineration facility to ensure compliance with standards and to ensure safety. If possible a certification programme should be instituted.
- Identify key performance indicators on their operations and services.
- Provide training for hospital or Ministry of Health staff on these indicators.
- Undertake an EIA as may be required by the Ministry of Environment and the Sub-Decree on Environmental Impact Assessment.
- Provide a description of the transportation fleet if it is a regional facility and it is considered a requirement that the operator of the facility provide this service.

d. Develop emergency response and contingency plans and thereafter train all personnel on these measures.

4.4.10. Safety and Hygiene Requirements:

a. Spill kits should include absorbents / adsorbents, disinfectants, buckets, shovel, torch, disposable container, and plastic waste bags with appropriate labelling. These should be placed where they are easily accessible and visible. Different spillage kits for different purposes should be marked.

b. Select fire extinguishers that are compatible with the types of potential fire hazards present and place them so they are visible from the front entrance and are not blocked by furniture and equipments. See **Appendix 3** for types of extinguishers.

c. Eyewash and deluge showers should be provided and these should be located within easy access.

d. Some means of communication should be provided. This could be telephone or two-way radio.

e. Appropriate PPE should also be provided.

f. Chemical safety data sheets (CSDS) for chemicals used as well as wastes handled should be available so that personnel are aware of the chemical properties and the safety requirements relating to these chemicals.

4.4.11. Management

a. Carry out periodic maintenance in accordance with the maintenance programme to replace or repair defective components. This should include maintenance of spare parts inventory, record keeping etc.

b. Staff should be periodically re-trained on all aspects of the operations of the facility as well as safety, ERP and CP requirements.

c. Develop performance indicators and carry out monitoring and analysis of these indicators.

d. Regularly submit reports to relevant agencies on their compliance with these key performance indicators and compliance with relevant regulatory requirements.

4.4.12. Factors to consider in deciding on an HCE-specific or regional incinerator:

a. An HCE-specific incinerator is one that is sited within the HCE premise and used only for the treatment of wastes generated in that HCE. Commercially available small, portable incinerators are now available, many of which claim to be able to meet emission standards.

b. A regional incinerator is one that is not sited within the HCE premise and serves as a treatment facility for wastes generated from several HCEs.

c. For a regional incinerator plant, receiving waste from multiple HCEs, other factors to be considered include:

- Whether transportation services from the relevant HCEs to the incinerator plant are available. If not the incinerator plant operator may consider having its own fleet to provide the service.

- The accessibility of the route from the HCEs to the incinerator plant facility. The access roads should also have appropriate load bearing capacities and should not be prone to floods, landslips etc.

5. Management of HCWM at the HCE

5.1. HCE Policy

Each HCE should develop an HCE specific policy, in line with the national policy. These HCE specific policies should include the following:

a. Designate the Head of the HCE as person responsible for HCWM.

b. Require the appointment of a Waste Management Officer (WMO).

c. Require the setting up of a Waste Management Team (WMT).

d. Identify the members, by position, that make up the WMT.

e. Identify the roles and responsibilities of the WMO and WMT members.

f. Require the development of a Waste Management Plan (WMP).

g. Identify the Terms of Reference (TOR) for the WMT meetings and the frequency of these meetings.

h. TOR of these meetings should include performance evaluation, contractor performance evaluation, safety and infection control issues, training needs assessment, periodic review of the WMP and improvements required.

i. Require that monitoring of the WMP is carried out.

j. Require that medical waste is treated in accordance with requirements of the PHCWM and other relevant legislations.

k. Require that medical waste be transported out by authorised contractors to authorised treatment facilities that meet best practice and international standards if treated at an off-site facility.

l. Generate monthly reports on HCWM generation and compliance to the WMP.

m. Since the key to affordable waste management is waste minimisation other policies of the HCE should incorporate elements that will ensure this. Hence the HCE's purchasing and stock management policies will need to be reviewed to ensure that the following elements are incorporated:

- Purchasing policy:
    - Avoid or minimise the purchase and use of materials and products that contain hazardous substances, therefore requiring the materials or product to be disposed as hazardous waste. Examples are mercury and aerosol cans.
    - Consider the purchase of comparable products with less packaging materials.

- Consider the purchase of reusable materials and equipments if the use of such materials and equipment do not impact negatively on infection control.
- Avoid the purchase of materials and products that would become hazardous, e.g. materials made of polyvinyl chloride (PVC).
- Ensures only required amounts of products that have expiry dates are purchased. Examples are chemicals and pharmaceuticals.

- Stock management policy:
  - Strict monitoring of expiration dates to prevent wastage.
  - Redistribution of stocks that are nearing expiration and which are not expected to be needed to other departments or HCEs to minimise wastage.

5.2. Organisational Structure

5.2.1. The Head of the HCE should be responsible for all matters in relation to HCWM. The roles and responsibilities should include the following:

a. Ensuring that a HCE-specific policy on HCWM is developed and implemented in line with the National Policy on HCWM.

b. Appointing a WMO.

c. Forming a WMT.

d. Appointing the WMO in writing with duties and responsibilities described in the appointment letter.

e. Appointing WMT members in writing with duties and responsibilities described in the appointment letter.

f. Ensuring that the WMT meets at the frequencies as stipulated in the HCE policy on HCWM.

g. Chairing the WMT meeting and ensuring that the TOR of the WMT meeting is complied with.

h. Ensure that a WMP is developed.

5.2.2. Members of the WMT, depending on the type of HCEs and staffing, may be as follows:

a. Head of the HCE – Chairman

b. Waste Management Officer

c. Hospital Engineer

d. Laboratory Manager

e. Pharmaceutical Officer

f. Infection Control Officer

g. Radiation Officer

h. Senior Matron

i. Department Heads

If manpower is limited, or for small HCEs, either the hospital engineer, laboratory manager, infection control officer or matron may be appointed to undertake the duties of a WMO.

5.2.3. The roles and responsibilities of the WMO should include the following:

a. He should be delegated with the authority to carry out his duties without interference of other HCE staff members.

b. He should report directly to the Head of the HCE.

c. He should serve as the Secretary of the WMT meetings.

d. He should be responsible to:

- Prepare the WMP with the assistance and feedback of the WMT members.
- Develop data collection forms in consultation with other WMT members.
- Develop guidelines and procedures specific to the HCE for approval by the WMT.
- Develop performance targets in consultation with the WMT for approval by the Head of the HCE.
- Monitor the implementation of the WMP.
- Organise the WMT meetings.
- Collate data and prepare monthly reports for presentation at the WMT meetings.
- Carry out training assessment needs for personnel involved in HCWM in the HCE.
- Conduct training for these relevant personnel.
- Prepare an annual budget for approval by the Head of the HCE.

5.2.4. In general the roles and responsibilities of the WMT members are:

a. Attend the WMT meetings.

b. In relation to their specialised field of work and areas under their authority they should:

- Provide data and information to assist in the development of the WMP.

- Monitor the implementation of the WMP.
- Assist in conducting training, e.g. handling of cytotoxic drug wastes, hazards of chemicals and incompatibility etc.
- Monitor and ensure implementation and compliance with the WMP and the HCWM policy.

5.3. Waste Management Plan

Each HCE should develop a waste management plan and this should include:

a. The Scope and Objectives of the Plan, i.e.
   - Waste categories that will be included in the plan.
   - The time horizon of the plan: 3, or 5 or 10 years.
   - Participants of the plan.

b. A description of the status in the HCE, and this should include:
   - Waste categories, waste sources and waste amounts by categories.
   - Current segregation, collection, storage and treatment options.
   - The treatment options available and costs involved.
   - Constraints, e.g. financing, manpower etc.

c. The Action Plan

   The changes needed in order to meet the HCE-specific Policy on HCWM, the National Policy on HCWM, PHCWM and other relevant legislations. This should include:
   - Organisational structure and management.
   - Financial elements:
     - Funding options, e.g. government budget, foreign aid etc.
     - Steps needed to obtain funding.
   - Implementation stages: If there are financial and other constraints, the WMP may need to be implemented in stages. In that case, the stages of implementation, and the timeframe, scope and targets for each stage of implementation should be defined.
   - Future planning and forecast: Future developmental plans for the HCE and how this will impact on the WMP should be incorporated.
   - Key performance targets should be established including how these will be monitored.

- Material requirements and facility capacities should be specified. Examples are:
    - Numbers and sizes of bags and containers required for segregation at every ward and department.
    - Numbers and sizes of containers for collection.
    - Capacity of the CHWS.
    - Treatment capacities required.
- The frequency of collection for the different categories of wastes should be determined and specified.
- The number of personnel required, e.g. number of collectors, container washers etc.
- A site plan showing the:
    - Location of containers for the different categories of wastes.
    - Collection routes through the HCE.
    - Location of the CHWS.
- Type of treatment used on-site for each category of waste.
- Name, address and type of off-site treatment facilities, if used, for each category of waste.
- Health and safety precautions.
- Pest control measures.
- An Emergency Response Plan, e.g. in case of spillage, accident etc.
- A Contingency Plan, e.g. during down-time of incinerator, insufficient supply of bags etc.

5.4. Standard Operating Procedures

Procedures on all HCWM activities, e.g. segregation, collection, storage should be developed. Work instructions may also need to be developed as a guide to workers and to ensure a standard of practice is maintained. Safety and health precautions should also be incorporated into these work instructions.

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