GLOBAL HEALTHCARE WASTE PROJECT

感染性醫療廢棄物的處置

衛福部 疾病管制署
中區傳染病防治醫療網
王任賢 指揮官

Steps in Healthcare Waste Management

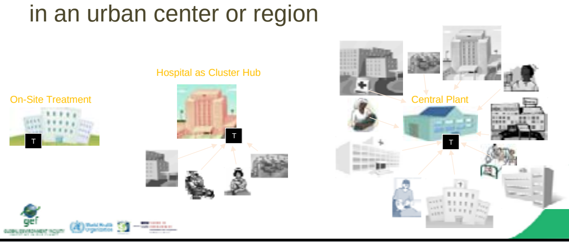
- Waste classification
- Waste segregation
- Waste minimization
- Handling and collection
- On-site transport and storage
- Treatment and disposal

Principles of Waste Treatment

- The main purpose is to reduce the potential hazard posed by healthcare waste in order to protect public health and the environment
- Treatment should be viewed in the context of the waste management hierarchy
- Measures should first be taken to minimize wastes, segregate and reuse non-infectious waste items wherever possible
- After minimization, the remaining waste materials should be treated to reduce the health and environmental hazards, and the residues should be properly disposed of

Treatment Approaches

- **On-site** – healthcare facility treats its own waste
- **Cluster treatment** – hospital treats its waste plus waste from other health facilities in a small area
- **Central treatment** – dedicated treatment plant collects and treats wastes from many health facilities in an urban center or region



Processes Used in the Treatment of Healthcare Waste

- Five basic processes are used for the treatment of hazardous healthcare wastes, particularly sharps, infectious and pathological waste:
  – Thermal
  – Chemical
  – Irradiation
  – Biological
  – Mechanical (used to supplement the other processes)

Thermal Treatment Processes

- Rely on heat to destroy pathogens
- Divided into two types:
  – High-heat thermal systems
  which involve combustion and/or pyrolysis of healthcare waste
  – Low-heat thermal systems
  also called non-burn or non-incineration treatment technologies

Low-Heat Thermal Process

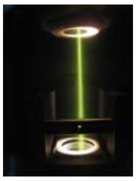
- Uses thermal energy at elevated temperatures high enough to destroy pathogens, but not sufficient to cause combustion or pyrolysis of waste
- Generally operates between 100ºC and 180ºC
- Takes place in moist or dry heat environments
  - Moist heat: uses steam to disinfect waste, commonly performed in an autoclave or other steam-based system; also referred to as a wet thermal process
  - Dry heat: uses heat without the addition of water or steam

Chemical Treatment Process

- Uses chemical disinfectants such as dissolved chlorine dioxide, bleach (sodium hypochlorite), peracetic acid, lime solution, ozone gas, or dry inorganic chemicals
- Often involves shredding, grinding, or mixing to increase exposure of waste to the chemical agent
- Treatment usually results in disinfection rather than sterilization
- For liquid systems, wastes may go through a dewatering stage to remove and recycle the disinfectant

Irradiation Process

- Uses irradiation from electron beams, Cobalt-60, or ultraviolet sources to destroy pathogens
- Effectiveness of pathogen destruction depends on absorbed dose by mass of waste
- Requires shielding to prevent occupational exposures
- Not commonly used for treating healthcare waste because of the high investment cost



Biological Treatment Process

- Specifically refers to the degradation of organic matter through processes occurring in nature
- Examples include composting, vermiculture, biodigestion, and natural decomposition through burial of cadavers, tissues and anatomical parts
- Some technologies add enzymes to speed up decomposition of organic waste
- Composting and vermiculture have been successfully used for placenta and hospital kitchen waste

Mechanical Process

- Generally supplement other treatment methods
- Includes shredding, grinding, mixing, and compaction which reduce waste volume, but are unable to destroy pathogens
- Shredders and mixers can improve rate of heat transfer and expose more surface area of wastes for treatment
- Mechanical methods should not be utilized before the waste is disinfected (unless the mechanical process is part of a *closed system* that disinfects air before it is released to the surrounding environment)
  - Workers could be at an increased risk of exposure to pathogens in the air if infectious waste is shredded or mixed in an open system before treatment

Factors in the Selection of Treatment Methods

- Types and quantities of waste for treatment and disposal
- Capability of the healthcare facility to handle the waste quantity
- Technological capabilities and requirements
- Availability of treatment options and technologies
- Capacity of system
- Treatment efficiency (microbial inactivation efficacy)
- Occupational health and safety factors
- Environmental releases
- Volume and/or mass reduction
- Installation requirements
- Space available for equipment

Factors in the Selection of Treatment Methods, cont'd.

- Operation and maintenance requirements
- Infrastructure requirements
- Skills needed for operating the technology
- Location and surroundings of the treatment and disposal sites
- Options available for final disposal
- Public acceptability
- Regulatory requirements
- Capital cost of the equipment
- Operating and maintenance costs of the equipment
- Other costs including costs of shipping, customs duties, installation and commissioning, transport and disposal of residues, and decommissioning

Environmental Considerations

- Most countries have ratified the Stockholm Convention on Persistent Organic Pollutants
- Under Article 5 of the Convention:
  Countries have to take measures to further reduce releases of dioxins and furans "with the goal of their continuing minimization and, where feasible, ultimate elimination."
- Annex C of the Convention:
  – Source with "the potential for comparatively high formation and release" of dioxins & furans: Medical Waste Incinerators

Environmental Considerations

- Under Annex C, Part IV of the Convention

  "[P]riority consideration should be given to alternative processes, techniques or practices that have similar usefulness but which avoid the formation and release of … [dioxins and furans]."

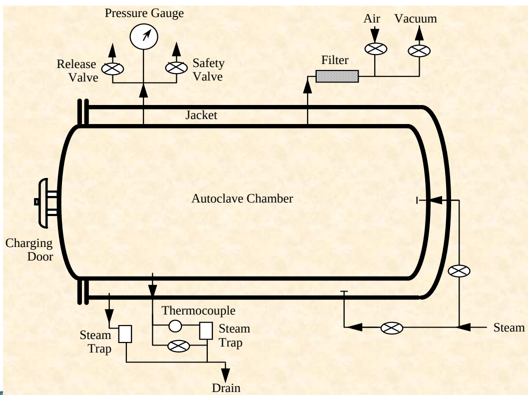
Examples of Treatment Technologies That Do Not Generate Dioxins/Furans

- Non-Burn Thermal Technologies
  – Autoclaves
  – Hybrid Steam Systems
  – Microwave Units
  – Frictional Heat Treatment
  – Dry Heat Systems
- Chemical Technologies
  – Alkaline Hydrolysis

Autoclaves

- Capable of treating a wide range of healthcare wastes
- Consists of a metal vessel designed to withstand high pressures, with a sealed door and an arrangement of pipes and valves through which steam is brought in and removed
- Removal of air from the vessel is essential to ensure penetration of heat into the waste
- The air that is removed must be treated to prevent the release of pathogenic aerosols, usually done with a high-efficiency particulate air (HEPA) filter or steam

Autoclave Schematic



Types of Waste Treatment Autoclaves

- Classification based on configuration
  - Horizontal
  - Vertical
- Classification based on how air is removed
  - Gravity displacement
  - Pre-vacuum
  - Pre- and post-vacuum
  - Pressure pulsing including multiple vacuum autoclaves

Testing Pathogen Destruction in Autoclaves and Other Steam-based Systems

Test methods involve microbial inactivation tests using microorganisms as biological indicators

Minimum disinfection requirement for healthcare waste:

4 Log reduction or higher of *Geobacillus stearothermophilus* or *Bacillus atropheus* spores

Resistance of microorganisms to steam disinfection

Microorganism	Examples
Highly resistant bacterial spores	*Geobacillus stearothermophilus*
Mycobacteria	*M. tuberculosis*
Non-lipid or small viruses	Polio virus, Hepatitis A virus
Fungi	*Aspergillus*
Vegetative bacteria	*Staphylococcus, Pseudomonas*
Lipid or medium-size viruses	HIV, HBV

Temperature, pressure and time needed for 6 Log reduction of spores in controlled lab conditions

Temp ˚C	Press (kPa)	Spore Kill time (min)
116	174	30
118	186	18
121	205	12
125	232	8
132	287	2
138	341	1

Note: Typical autoclave operating conditions of 121 ºC for 30 min must be tested using biological indicators

Autoclaves

- Autoclaves generate significantly less air pollutants than incinerators and other high-heat thermal processes.
- Volatile and semi-volatile organic compounds, cytotoxic waste, mercury, other hazardous chemical waste, and radioactive waste should not be treated in an autoclave
- Odors can cause problems around autoclaves if there is insufficient ventilation
- Waste streams need to be properly segregated in order to prevent hazardous chemicals from being placed in the treatment chamber
  - Poorly segregated waste may emit low levels of alcohols, phenols, formaldehyde, and other organic compounds in the air and pose health risks to the autoclave operators and waste workers
- Treated waste from an autoclave will retain its physical appearance; shredding (though prone to break downs) may reduce the volume 60-80%

Why Preventive Maintenance is Essential

- Enhances safety by avoiding serious accidents
- Increases the efficiency of the technology
- Ensures that the treatment technology continues to reduce the hazards of healthcare waste
- Extends the life of the technology
- Avoids downtime due to equipment breakdowns
- Saves on the cost of repairs, spare parts, and unscheduled maintenance
- Reduces energy consumption

Preventive Maintenance

- Healthcare facilities should work with equipment vendors and manufacturers to develop a detailed preventive maintenance schedule
- Technology operators should be trained in simple preventive maintenance

- Maintenance logs should be maintained
- Facility engineers and managers should monitor maintenance procedures

Autoclave Operation

- A typical operation for an autoclave involves:
  - Waste collection
  - Pre-heating
  - Waste loading
  - Air evacuation (by gravity or vacuum)
  - Steam treatment
  - Steam discharge
  - Unloading
  - Documentation
  - Mechanical treatment (compaction or shredding if desired)

Autoclave Maintenance

- Autoclaves can last for many years if properly maintained
- Example of a typical preventive maintenance schedule
  - Daily maintenance by operator: check for leaks, cleanliness of the chamber, filter screen and door seal
  - Weekly maintenance by operator: check indicator lights, compare temperature & pressure gauges with recordings
  - Monthly maintenance by operator: check door gasket or O-ring, conduct microbiological tests (by lab personnel)
  - Quarterly maintenance by the engineer: checking valves, pipes, joints, strainers, drains; checking control system, interlocks and electricals; testing air removal efficiency
  - Annual maintenance by the engineer: check for corrosion and wear, check thermocouples, water level indicators, gauges, relief valves and other safety devices, and control functions.

Examples of Small to Medium Autoclaves


Dual autoclaves in Senegal



Electric or gas-powered autoclave in Tanzania (stationary and truck-mounted)

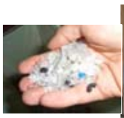

Hospital-based autoclave in the US



Solar-powered autoclave in India

Example of a Medium-Size Autoclave in Tanzania

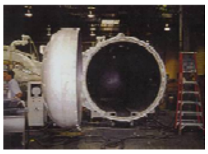



Examples of Large-Scale Autoclaves for Central Treatment Plants


Large-scale autoclave in the Philippines


5-tonne per hour autoclave in Vietnam


Large autoclave, 2.4 m dia x 9.7 m long


Two large-scale autoclaves in South Africa

Post-Treatment Shredders Designed for Healthcare Waste





Source: Mercodor, Mark Costello/Vecoplan, Aduromed

Example of a Modular Autoclave System



Integrated autoclave found in North and South America, Europe, Middle East, New Zealand and Asia

Autoclaves and Re-melting of Materials

- Disadvantage of autoclaves: waste is not physically altered after treatment, thus shredders or compactors are needed to reduce volume
- Advantage of autoclaves: the sterilized glass, plastic and metal waste can be recovered after treatment and re-melted to produce other products, thus reducing landfill waste

Example of Autoclaves and Re-melting

Himalayan Institute Hospital Trust, India

Collection of sharps in autoclavable pails

HIHT Hospital → Autoclave → Shredder → Separation by Gravity → Plastics - recycled / Metals –burial

Source: HIHT

Example of Autoclaves and Re-melting

Hub cutter used to separate needles and plastic syringe parts

Sharps waste → Hub cutter → Collect needles → Treat in an on-site autoclave → Bury in a pit

Hub cutter → Collect plastic syringe → Treat in an on-site autoclave → Shred → Recycle at plastics plant

Swiss Red Cross project in Kyrgyzstan

Plastics re-melted to make coat hangers, flower pots and electrical covers

Hybrid Steam-based Systems

- Hybrid or integrated technologies have been developed for the purpose of improving heat transfer to waste, achieving more uniform heating of waste, rendering waste unrecognizable, and/or making the treatment a continuous process
- Like autoclaves, these systems also use steam, but they incorporate mechanical processes before, during, and after treatment
- Examples include
  - Steam treatment-mixing-fragmenting followed by drying and shredding
  - Internal shredding followed by steam treatment-mixing and then drying
  - Internal shredding-steam treatment-mixing followed by drying
  - Internal shredding followed by steam treatment-mixing-compaction

Example of a Hybrid Steam System: Autoclave with Internal Fragmentation and Mixing

Hybrid autoclave used in Canada, China, Egypt, Greece, India, Lebanon, Mexico, Niger, Russia, South Africa, and other countries

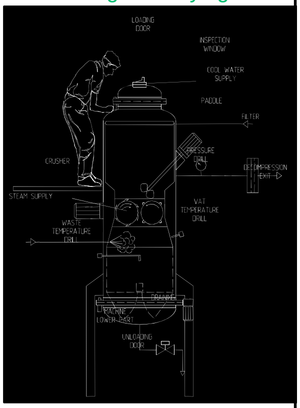
Example of a Hybrid Steam System: Rotating Autoclave with Internal Mixing-Fragmenting, Drying and Post-treatment Shredding

Rotating autoclave used in American Samoa, Canada, Latvia, Mexico, United Kingdom, United States and other countries

Source: Tempico

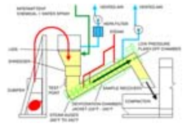
Example of a Hybrid Steam System: Vertical Autoclave With Internal Shredding and Drying

Hybrid vertical autoclave used in Albania, Argentina, Brazil, China, Cyprus, Ecuador, Egypt, Honduras, Jordan, Lebanon, Mexico, Nigeria, Panama, Syria, UAE, Venezuela and other countries



Example of Continuous Steam Treatment with Internal Shredding, Mixing and Drying

1000 pounds per hour unit



Continuous steam treatment system used in Australia, England, Ireland, Northern Ireland, United States and other countries

Source: STI Chem-Clav

Internal Shredding of Waste

- Shredding before disinfection can only be done in a closed system to avoid releasing any pathogens into the air
- Shredding is used for the following reasons:
  - To increase surface area of contact between waste and disinfectant eliminating voids in the waste load
  - To render any anatomical parts unrecognizable to avoid adverse visual impact on disposal
  - To reduce the volume of waste (shredding plus compacting before disinfection can reduce original waste amount 60-90%, depending upon equipment used)

Microwave Treatment Technologies

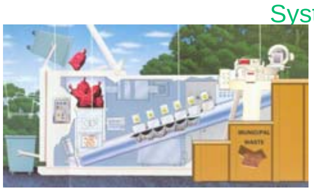
- Disinfection by moist heat and steam generated by microwave energy
- Magnetrons (microwave generators) convert electrical energy into microwave energy
- Some systems use temperatures around 97-100ºC with long exposure times. In other systems, steam under pressure is used to achieve temperatures as high as 140ºC.

Example of Small to Medium Microwave Systems

Microwave units used in Austria, Bulgaria, Czech Republic, Ecuador, Ethiopia, France, Germany, Greece, Hungary, India, Indonesia, Iran, Kuwait, Latvia, Lithuania, Malaysia, Nigeria, Poland, Romania, Serbia, Turkmenistan, UK and other countries

Sources: Sintion, Meteka, Sterifant

Examples of Large-scale Continuous Microwave Systems



Large microwave units used in Brazil, France, Philippines, Russia, South Africa, South Korea, United States, Maghreb countries in North Africa, as well as other countries in South America, Middle East and Asia

Sources: Sanitec, Micro-Waste, AMB Ecosteryl

Examples of Frictional Heat Treatment Systems



Frictional heating units are found in Botswana, Brazil, Bulgaria, Canada, Chile, China, Dominican Republic, Egypt, France, Greece, Hungary, Iran, Kazakhstan, Mexico, Netherlands, Paraguay, Poland, Romania, Russian Federation, Spain, Turkey, Uruguay and other countries

Sources: Newster, Ompeco

Examples of Small Dry Heat Systems






Chemical Treatment Technologies

- Powerful disinfectants are required
- Disinfection efficiency depends on the operational condition within treatment equipment
  - kind and amount of chemical used
  - contact time and extent of contact between disinfection and waste
  - organic load of waste
  - operating temperature, humidity, pH
- Only the surface of intact solid waste items will be disinfected
- Internal shredding or milling of wastes is likely necessary before disinfection

Chemical Treatment Technologies

- Eliminate microorganisms, or reduce the amount to an acceptable level
- Microbial inactivation tests are important to ensure that the concentrations and exposure times sufficient
- Since many disinfectant solutions lose their ability to destroy pathogens with time and organic load, the strength of the disinfecting solution should be monitored
- Many chemical disinfectants are themselves hazardous and toxic, so proper precautions should be exercised and PPE worn for safety. Wastewater discharges should also be monitored.


Examples of Chemical Treatment System


These chemical waste systems are found in some countries in Europe and in the US. One uses chlorine dioxide and the other uses a mixture including glutaraldehyde and quarternary ammonium salts.

Alkaline Hydrolysis Technologies

- Also called tissue digesters
- Used for anatomical waste (body parts), organs, tissues, placenta, contaminated animal waste, and cadavers; also destroys formaldehyde and some cytotoxic waste
- Process involves placing waste in stainless steel vessels and treatment with steam and alkali (sodium or potassium hydroxide)
- The main solid residue remaining from high pressure alkaline hydrolysis is calcium

Examples of Alkaline Hydrolysis Systems


4500 kg units


Typical residues from alkaline hydrolysis


21 kg units

Sources: WR2, BioSafe Engineering, PRI, Bio-Response, Peerless

Non-Incineration Technology Resources

- ❖ *Compilation of Vendors of Waste Treatment Autoclave, Microwave, and Hybrid Steam-Based Technologies* (UNDP GEF, 2012)
- ❖ *Compendium of Technologies for the Destruction of Healthcare Waste* (UNEP, 2012)
- ❖ *Non-Incineration Medical Waste Treatment Technologies* (HCWH, 2001) and *Non-Incineration Medical Waste Treatment Technologies in Europe* (HCWH, 2004), available from Health Care Without Harm in www.noharm.org

Note: The UNDP GEF Project does not endorse any specific technology, company, or brand name.

Disposal Methods

- Healthcare wastes properly treated in autoclaves, hybrid steam-based systems, microwave units, frictional heat systems, and dry heat systems
  - are sterilized or decontaminated to high disinfection levels
  - have far fewer microorganisms or practically no microorganisms compared to household waste
  - can be discarded with regular waste in a landfill
- Special measures have to be taken for sharps waste (e.g., encapsulation or shredding) if discarded in a poorly controlled dumpsite

Disposal in a Landfill

- Elements of a sanitary landfill
  - Geological stability and geological isolation from the environment, located far from sensitive areas
  - Sealing of the bottom and sides using clay and geo-membrane liners
  - Collection and treatment of leachate and runoff
  - Recovery of landfill gas
  - Groundwater monitoring
  - Controlled access and controlled operations
  - Organized deposits of waste in cells
  - Compaction and daily cover
  - Site closure plan to minimize infiltration

Uncontrolled Dumping in Low-Resource Settings

- Characterized by the scattered and uncontrolled deposits of waste at a site and the presence of unprotected waste pickers (scavengers) leading to increased risk of infection for humans and animals

UNTREATED HEALTHCARE WASTE SHOULD NOT BE DISPOSED OF AT AN UNCONTROLLED DUMPSITE!

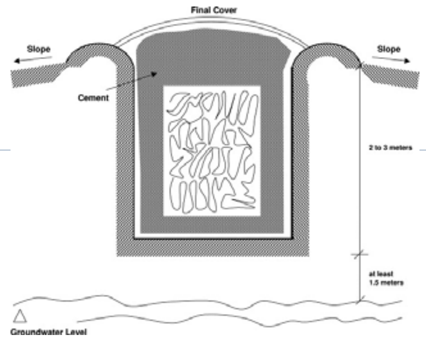
Upgrading Land Disposal in Low-Resource Settings

- **Path from open dumping to "controlled dumping":** Reduce working area of the site, cover unneeded areas with soil, extinguish fires, and control scavengers
- **Path from controlled dumping to "engineered landfill":** prevent surface water from entering, extract and spread soils to cover wastes, gather leachate into lagoons, spread/compact waste into thinner layers, excavate new areas and isolate with plastic sheeting
- **Path from engineered landfill to "sanitary landfill"**: Improve engineer-ing techniques, install landfill gas control and environmental monitoring, train and organize the work force, keep records, and treat the leachate

Encapsulation of Healthcare Waste in Low-Resource Settings

- Process whereby waste containers are filled, an immobilizing agent is added, and the containers are sealed
- Boxes made of high-density polypropylene or metal drums can be 3/4th filled with sharps, or chemical or pharmaceutical residues and immobilizing material (e.g., plastic foam, bituminous sand, cement mortar, or clay) is added and the box is sealed and buried

Encapsulation Schematic



Inertization of Healthcare Waste in Low-Resource Settings

- Process in which waste is mixed with cement and other substances before disposal so as to minimize the risk of leaching into nearby surface water and groundwater
- Especially suitable for pharmaceuticals and incineration ash with high metal content
- Process is inexpensive and does not require sophisticated mixing equipment

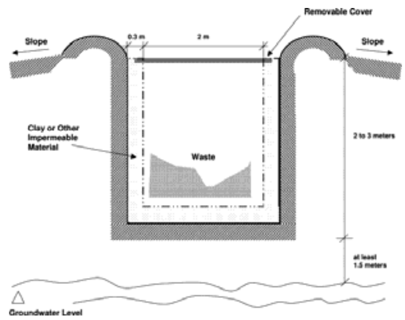
Disposal of Untreated Healthcare Waste in Low-Resource Settings

- If a healthcare facility has no other option but to deposit untreated waste in the municipal landfill, there are two options:
  - Burial in a shallow hollow excavated in mature municipal waste immediately in front of the base of the working face where waste is being tipped; after deposit, the waste should be covered the same day; prevent scavenging.
  - Burial in a deeper pit excavated in a covered area of mature municipal waste, fill back up with the mature municipal waste that was removed, and also an intermediate soil cover (approx. 30 cm); prevent scavenging.

Disposal of Untreated Healthcare Waste in Low-Resource Settings

- Another option is safe burial on hospital premises
- If this approach is taken, the hospital should set the following safety measures for the site:
  - Restrict access to authorized personnel
  - Line the bottom with a material of low permeability, such as clay, dung, and river silt, to prevent pollution of groundwater and wells
  - Prevent new water wells from being dug nearby
  - Bury only infectious healthcare waste
  - Limit burial of chemical wastes to smaller quantities so as to prevent pollution
  - Manage the pit as a landfill, with each layer of waste covered by a layer of soil to prevent odors and contact with decomposing waste, and to deter rodents and insects

Schematic of a Burial Pit on Hospital Premises



Discussion

- What regulations or policies exist in your country or region regarding treatment and disposal methods for healthcare waste?
- What are some factors that your facility considers when deciding on a waste treatment method? What do think is important when evaluating which method would be most appropriate?
- What are some non-incineration treatment technologies that are used in your facility? Which do you think work best or should be used?
- What disposal methods are used at your healthcare facility?
- What are the barriers to using new treatment technologies? How can we overcome these barriers?