CLINICAL SOLID WASTE MANAGEMENT PRACTICES AND ITS IMPACT ON HUMAN HEALTH AND ENVIRONMENT

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ABSTRACT

The management of clinical solid waste (CSW) continues to be a major challenge, particularly, in most healthcare facilities of the developing world. Inappropriate disposal methods and improper handling exercised during handling and disposal of CSW is increasing significant health hazards and environmental pollution due to the infectious nature of the waste. In most of the cases, the main reasons of the mismanagement of CSW are the lack of appropriate legislation, specialized clinical staffs, awareness and effective control. Proper handling, treatment and disposal of clinical waste play a vital role in infection control. Most of the developing countries are looking for cost effective disposal methods of clinical wastes due to financial difficulties. Recycle-reuse program of CSW materials can be continued after sterilization by using Supercritical fluid carbon dioxide (SF-CO$_2$) sterilization technology at the point of initial collection which inactivates the infectious micro organisms in CSW. This technology reduces exposure to infectious waste, decrease labor, lower costs and yield better compliance with regulatory. Thus healthcare facilities can save money and provide safe environment for patients, health care and clinical staffs. This review mainly emphasizes on the various technologies and techniques like Incineration, Autoclaving, Microwaves, Supercritical fluid carbon dioxide sterilization which are used to treat clinical wastes.

KEYWORDS: Clinical Solid Waste, Disposal methods, Supercritical fluid carbon dioxide sterilization method.
1. INTRODUCTION

In the last few decades, human activities and changes associated with lifestyles and consumption patterns have resulted in the generation of huge volumes of different types of wastes. In recent years, concern over the solid waste from healthcare facilities (HCFs) (i.e., hospitals, clinics, pathological laboratories, pharmacies and other supported healthcare services) has increased throughout the world. Improper clinical solid waste management practice impacts both directly and/or indirectly to healthcare staffs, patients and hospitals environment. Diseases like cholera, dysentery, skin infection, infectious hepatitis can spread epidemic way due to the mismanagement of clinical solid waste. Therefore, it is urgent to determine appropriate methods for the safe management of clinical solid waste.

The main aims of this review are as follows

(i) Summarizes the information of clinical solid waste generation and disposal options in the world, particularly, in some developing countries.
(ii) Determine the risk assessment on unsafe handling of clinical solid waste.
(iii) Determine the best appropriate technology for the safe disposal of clinical solid waste.

The poor management of clinical solid waste is a significant problem in most economically developing countries. Successful clinical waste management represents a challenge in developing countries due to:

- Insufficient financial investment,
- Lack of awareness and effective control,
- Lack of trained clinical staffs in the waste management framework.
- Absence of healthcare waste management guideline and legislation in country level
- Unavailability of suitable treatment and disposal option.

The study took into account the shortcoming issues of existing clinical solid waste management practice including waste generation, handling, segregation, risk assessment during handling and treatment to determine the best appropriate technology for safe management of clinical solid waste.

2. WHAT IS CLINICAL WASTE: DEFINITION AND CLASSIFICATION

The waste generated in HCFs does not have a clear definition. There are currently several terms used to describe waste that is generated from healthcare facilities. It can lead to
problems as it is important to have a specific definition of those wastes derived from healthcare premises. In literature, the terms ‘Clinical waste’, ‘Health care waste’, ‘Infectious waste’ and ‘Medical/Hospital waste’ are typically encountered, they may have similar meanings or be subsets of one another, which substantially inhibits using and comparing data from different countries.\(^4\)

General classification of wastes arising from HCF’s are mentioned in Table 1.\(^5\text{-}^9\)

**Table 1: Definition and general classification of wastes arising from Health Care Facilities (HCF’s)**

<table>
<thead>
<tr>
<th>Definition</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health care waste (HCW)</td>
<td>General waste and Medical waste</td>
</tr>
<tr>
<td></td>
<td>Hazardous and non-hazardous</td>
</tr>
<tr>
<td>Hospital waste</td>
<td>General waste, Medical waste and sharp</td>
</tr>
<tr>
<td></td>
<td>General waste and Hazardous waste</td>
</tr>
<tr>
<td></td>
<td>Hazardous waste and non-hazardous waste</td>
</tr>
<tr>
<td>Medical waste</td>
<td>Infectious waste and General Medical waste</td>
</tr>
<tr>
<td></td>
<td>General waste and Special waste</td>
</tr>
<tr>
<td></td>
<td>Domestic waste and hazardous waste</td>
</tr>
<tr>
<td></td>
<td>Infectious and Municipal waste</td>
</tr>
<tr>
<td></td>
<td>Tissues and others</td>
</tr>
</tbody>
</table>

HCW can be classified as non-clinical waste (non regulated HCW, also can define as general waste), and clinical waste (special waste, regulated HCW). The HCW can be further characterized as shown in Fig 1.\(^{10}\)

![Fig 1: The categories of wastes from HCF’s](image-url)
Non-clinical waste is defined as such waste that is not posing any risk to human health or environment. Examples of non-clinical waste include packaging materials such as cardboard, office paper, leftover food, cans etc.

Clinical waste is defined by the Controlled Waste Regulations (1992) as (a) Any waste which consists entirely or partly of human or animal tissue, blood or other body fluids, excretions, drugs or other pharmaceutical products, swabs or dressings or syringes, needles or other sharp instruments, being waste which unless rendered safe may prove hazardous to persons coming into contact with it.

(b) Any other waste arising from medical, nursing, dental, veterinary, pharmaceutical or similar practice, investigation, treatment, care, teaching or research or the collection of blood from transfusion, being waste which may cause infection to any person coming into contact with it.

Clinical wastes include different types of wastes such as infectious waste, radioactive waste, chemical waste, pathological waste, pharmaceutical wastes etc. Examples of different types of clinical waste are given in Table 2.[6,8]

Table 2. Examples of types of clinical waste.

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infectious waste</td>
<td>Lab cultures and stocks of infectious agents, wastes from isolation wards, tissues, materials or equipments that have been in contact with infected patients</td>
</tr>
<tr>
<td>Pharmaceutical waste</td>
<td>Expired and unnecessary pharmaceuticals and Drugs</td>
</tr>
<tr>
<td>Pathological waste containing human tissues and fluids</td>
<td>Body parts, human fetuses, blood and other body fluids</td>
</tr>
<tr>
<td>Chemical waste</td>
<td>Solid, liquid and gaseous chemicals from diagnostic and experimental work, cleaning materials</td>
</tr>
<tr>
<td>Radioactive waste</td>
<td>Radioactive substances including used liquids from radiotherapy and lab work</td>
</tr>
<tr>
<td>Sharps</td>
<td>Needles, Syringes, Blades, Broken glass, Scalpels etc</td>
</tr>
</tbody>
</table>

3. SOURCES OF CLINICAL WASTE

The principle sources of clinical waste are
Hospitals and clinics, particularly those providing acute services, i.e., offering Operating Theatres, Maternity ward, Accident & Emergency, Mortuary, Intensive Care, Isolation Wards, Pharmacy, Pathology Laboratories and other research facilities.[4]

Other sources of clinical waste are ambulance services, public health laboratories, blood donation centers and blood banks, practice center of doctors, dentists, veterinary surgeons, immunization/vaccination clinics and hospitals, clinics and nursing homes providing community care, care of the elderly and services related to mental health and learning disabilities.[11]

There has been an increase in the amount of clinical waste coming from households. This is due in part to changes in health care policies. Both medical devices and instruments are used while treating patients at home, thereby producing a variety of waste materials. Self-injecting diabetics and people changing colostomy bags at home can also generate significant quantities of clinical waste.

4. CLINICAL WASTE GENERATION
Generally, quantities of the waste generation rate in healthcare centers depends on type of healthcare establishment, availability of instrumentation, general condition of HCFs area, ratio of disposable item in use and number of patient care. Also, the economic, social and cultural status of the patients might change the amount of waste generation. The healthcare waste generation rate depends on the size and the type of the medical institution, but also that it differs from country to country based on the level of economic development. The developed countries generate higher amounts of healthcare waste than that of the developing countries.[7,12,13,14]

Data from World Health Organization also reveal that.

- North America produces 7–10 kg of healthcare waste per bed/day, whereas South America produces 3 kg of waste per bed/day.
- This difference was also found in Europe and Asia. Western Europe produces 3–6 kg, whereas Eastern Europe 1.4–2 kg of waste per bed/day.
- In Asia, richer countries produce 2.5 kg per bed/daily, and poorer countries 1.8–2 kg per bed/daily.
5. HANDLING OF CLINICAL SOLID WASTE

Unless clinical waste is properly handled and disposed, it can present risks to healthcare staffs, the public and the environment. Consequently, many developed countries have devised codes of practices and guidelines for handling and disposal such waste. However, in most developing countries, clinical waste has not received adequate attention despite the fact that clinical waste labeled as hazardous or infectious. Clinical solid waste may contain potential pathogenic micro-organisms. Therefore, clinical solid waste is perceived by many as hazardous or infectious.

The management of clinical solid waste, particularly in developing countries is often poor and fraught with difficulties. In developing countries, clinical solid waste has been handled and disposed together with the non-clinical waste, which is creating inevitable risks to the health care workers, publics and the environment. Healthcare workers are not educated enough and most of them have not had any special training on the management of clinical waste. Generally, they use bare hands during collection and sorting the waste. Most of the healthcare institutions do not have appropriate color coded bags or containers for sorting the different types of waste. Healthcare waste are not sorted because of the high fee of their disposal cost, therefore both clinical and non-clinical waste are mixed together and dump illegally. Even most of the hospitals have not any special place for the storage the clinical waste prior to disposal. Wastes are placed in an unsecured area until collected and is fully accessible to the animals.\textsuperscript{[12,15]}

6. BIOMEDICAL WASTE MANAGEMENT RULE

Bio-Medical Waste Management Rules are published on 20/07/1998 under Environment Protection Act, 1986. As per this rule every occupier of an institution generating bio medical waste which includes hospitals, nursing home, clinic, dispensary, veterinary institutions, animal house, pathological laboratories, blood banks to take all steps to ensure that such a waste is handled without any adverse effect to human health and environment.\textsuperscript{[16]}

Different categories of Biomedical wastes and their treatment methods are explained in Table 3.\textsuperscript{[17]}
Table 3: Bio medical wastes and their treatment methods

<table>
<thead>
<tr>
<th>Option</th>
<th>Treatment &amp; Disposal</th>
<th>Waste category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat No:1</td>
<td>Incineration / deep burial</td>
<td>Human Anatomical Waste (human tissues, organs, body parts)</td>
</tr>
<tr>
<td>Cat No:2</td>
<td>Incineration / deep burial</td>
<td>Animal Waste Animal tissues, organs, Body parts carcasses, bleeding parts, fluid, blood and experimental animals used in research, waste generated by veterinary hospitals/ colleges, discharge from hospitals, animal houses</td>
</tr>
<tr>
<td>Cat No:3</td>
<td>Local autoclaving/waving/ incineration</td>
<td>Microbiology &amp; Biotechnology waste (wastes from laboratory cultures, stocks or specimens of micro-organisms live or attenuated vaccines, human and animal cell culture used in research and infectious agents from research and industrial laboratories, wastes from production of biological, toxins, dishes and devices used for transfer of cultures)</td>
</tr>
<tr>
<td>Cat No:4</td>
<td>Disinfections (chemical treatment autoclaving/micro waving and mutilation shredding)</td>
<td>Waste Sharps (needles, syringes, scalpels blades, glass etc. that may cause puncture and cuts. This includes both used &amp; unused sharps)</td>
</tr>
<tr>
<td>Cat No:5</td>
<td>Incineration/destruction &amp; drugs disposal in secured landfills</td>
<td>Discarded Medicines and Cytotoxic drugs (wastes comprising of outdated, contaminated and discarded medicines)</td>
</tr>
<tr>
<td>Cat No:6</td>
<td>Incineration/autoclaving/micro Waving</td>
<td>Soiled Waste (Items contaminated with blood and body fluids including cotton, dressings, soiled plaster casts, linebeddings, other material contaminated with blood)</td>
</tr>
<tr>
<td>Cat No:7</td>
<td>Disinfections by chemical treatment waving&amp; mutilation shredding</td>
<td>Solid Waste (waste generated from disposable items other than the waste sharps such as tubing, catheters, intravenous sets etc.)</td>
</tr>
<tr>
<td>Cat No:8</td>
<td>Disinfections by chemical treatment And discharge into drain</td>
<td>Liquid Waste (waste generated from laboratory &amp; washing, cleaning, housekeeping and disinfecting activities)</td>
</tr>
<tr>
<td>Cat No:9</td>
<td>Disposal in municipal landfill</td>
<td>Incineration Ash (ash from incineration of any bio-medical waste)</td>
</tr>
<tr>
<td>Cat No:10</td>
<td>Chemical treatment discharge into drain for liquid &amp; secured landfill for solids</td>
<td>Chemical Waste (chemicals used in production of biological, chemicals, used in disinfection, as insecticides, etc)</td>
</tr>
</tbody>
</table>

7. TREATMENT OF CLINICAL WASTE
The WHO directed that the selection of clinical waste disposal methods must be cost effective, easily implemented and environmental friendly.[18]
A proposed waste disposable method must have:

- minimal risk assessments for proposed waste management facilities,
- minimal human health impacts
- minimal environmental impacts and
- cost effective.

Relatively, several technologies have been conducted to treat clinical waste for the inactivation of potentially pathogenic micro-organisms so that the waste no longer poses a danger to public health and safety. But none of these practices are able to adequately inactivate the micro-organisms, since each practice has its own weakness and disadvantage, thereby the urgency to find an efficient method to preserve human health and environment. It is found from literatures[3,4,6] that the most common disposal methods of clinical solid waste, particularly in developing countries, are:

- Open dumping,
- Landfill or incineration.
- Steam sterilization or autoclaving,
- Chemical sterilization,
- Microwaving, etc.

7.1. Open dumping
Open dump is the most common method of clinical waste disposal in developing countries.[3,19] This is probably less expensive and no other alternative methods are available at this reasonable cost. Clinical waste should not be deposited on or around open dumps.

Disadvantages

- It is a potential infection source of public health and environmental pollution.
- This uncontrolled clinical waste transmits infectious pathogenic micro-organisms to the environment either via direct contact through wounds, inhalation, or ingestion, or indirect contact through the food chain or a pathogenic host species.
- Also wind easily blows over the dumped waste, dispersing air pollutants to nearby communities.[3,6]
- Burning is aimed to reduce the volume of waste and stopping the spread of papers. The burning itself is a potential source of generating toxic emissions. This is more likely since
wastes such as plastics, syringes and paper are burned together. There is high chance that toxic chemicals like dioxins and furans are generated and separating air pollutants.[6]

7.2. Landfill
In general, landfill is an easy and low cost waste disposal method. But, if a landfill is not properly managed, it raises human health risk and environmental pollution concern. However, landfill is considered an unsophisticated disposal method, which requires careful segregation of waste so that it does not pose significant health effects on public health and environment. In developing countries, landfills are operated like an open dump.

Waste can be dispose in a ‘Sanitary landfill’, after it has been properly sorted. Sanitary landfill is a modern engineering landfill where waste is allowed to decompose into biologically and chemically inert materials in a setting isolated from the environment.[18,20]

Disadvantages

- Land disposal of clinical solid waste is often done in low lying areas of an open land, which may prone to flooding, increasing the possibility of surface water contamination during the rainy season.
- The main potential impacts on health arise from inhaled landfill gas and exposure to groundwater contaminated by landfill leachate. Although landfill gas consists mainly of methane and carbon dioxide, it can contain a large number of other gases at low concentrations, some of which are toxic. The major components of landfill gas, methane and carbon dioxide, are ‘greenhouse gases (GHGs). Both gases are major constituents of the world’s problem GHGs.
- Leachate, on the other hand, poses a threat to surface and ground water systems. It has also been reported that leachate from solid waste landfill site may be mutagenic and carcinogenic.[10]

7.3. Incineration
The numerous advantages of incineration have led to its worldwide use as the preferred means of treating and disposing clinical solid waste.

Incineration is a high-temperature dry oxidation process that converts the waste into residual ash and gases. It is particularly useful in the treatment of pathological waste as these components of the waste stream are rendered unrecognizable.[8,21]
This process is usually selected to treat wastes that cannot be recycled, reused, or disposed of in a landfill site. Incineration emits lots of harmful pollutants including particular concern carbon monoxide (as a result incomplete combustion), hydrogen chloride, metals (e.g. mercury lead, arsenic, cadmium) dioxin and furan. Many of these pollutants, dioxins in particular, can be carried long distance from their emissions source and accumulate in soil, water and food source and pollute them.

It is reported that a properly designed incinerator can completely burn waste and leave minimum residual in the form of ashes, whilst minimizing the exposure risks to emissions through the correct placement of the units in relation to the clinic and the surrounding communities. Unfortunately, especially in developing country’s hospitals, most of the incinerators are in poor design and have operational problems. The incinerators are local made and it is constructed from burned bricks and cement. Waste is burned using coal as fuel, which cannot produce require temperature to properly burn the waste. Therefore, high amount of ash is generated because of incomplete burning of waste.[22]

7.4. Autoclave Treatment
Since 1876, autoclaves have been used for the sterilization of various kinds of infectious hospital waste.[23] Autoclaves are generally used to treat sharps, items contaminated with blood, residues from surgery and from isolation wards, bandages, gauze, linen, gowns and other similar materials and non-chemical laboratory wastes. The autoclaves have a temperature range of 50–250°C, but they are operated at 160°C as the optimum temperature to kill bacteria. Autoclave of clinical waste is considered as an alternative technology of the incinerator.

Disadvantages[24]
- More costly method than incineration because, it is the double treatment option of clinical solid waste.
- It cannot handle large quantities of hazardous waste.
- Autoclave cannot treat a variety of chemical and hazardous substances such as wastes from chemotherapy treatment, mercury, volatile and semi-volatile organic compounds, radioactive wastes, and other hazardous chemical wastes
- It is not suitable to treat large body parts, animal carcasses, or other large items that, because of their mass and other characteristics, which make it difficult or time consuming for the entire material to reach the prescribed temperatures.

7.5. Hydroclave Treatment\[16\]
Hydroclave is an innovative equipment for steam sterilisation process (similar to autoclave). It is a double walled container, in which the steam is injected into the outer jacket to heat the inner chamber containing the waste. Moisture contained in the waste evaporates as steam and builds up the requisite steam pressure (35-36psi). Sturdy paddles slowly rotated by a strong shaft inside the chamber tumble the waste continuously against the hot wall thus mixing as well as fragmenting the same. In the absence of enough moisture, additional steam is injected. The system operates at 132\( ^{0}\)C and 36 psi steam pressure for sterilisation time of 20minutes. The total time for a cycle is about 50 minutes, which includes start-up, heat-up, sterilisation, venting and depressurisation and dehydration. The treated material can further be shredded before disposal. The expected volume and weight reductions are upto 85\% and 70\% respectively. The hydroclave can treat the same waste as the autoclave plus the waste sharps. The sharps are also fragmented.

Advantages
- Absence of harmful air emissions, absence of liquid discharges,
- Non requirement of chemicals,
- Reduced volume and weight of waste etc.

7.6. Microwaves
Microwaves are electromagnetic waves with frequencies between radio and infrared waves. It is important that the waste is wet, either as a result of naturally occurring moisture or by the addition of steam, in order to create the thermal process. Some treatment processes utilize microwaves to heat water to form steam, which is then applied to the clinical waste stream. Some systems apply low frequency radio waves to inactivate micro-organisms contained within the waste. The microwaves heat the clinical waste from the inside of the materials to their external surfaces. Microwaving clinical waste might be economically competitive compared to the incinerator.\[8, 25\]

Disadvantages
- Nevertheless microwave technology is not suitable for large scale treatment.
The treatment cost is also expensive and is not affordable for the developing countries.

Surveys also reported that microwaving of clinical waste refers inadequate microorganism sterilization capability.

7.7. Chemical disinfec
ting

This treatment is recommended for waste sharps, solid and liquid wastes as well as chemical wastes. Chemical treatment involves use of at least 1% hypochlorite solution with a minimum contact period of 30 minutes or other equivalent chemical reagents such as phenolic compounds, iodine, hexachlorophene, iodine-alcohol or formaldehyde-alcohol combination etc. Preshredding of the waste is desirable for better contact with the waste material. [16]

8. DETERMINATION OF SUITABLE METHOD

It appears that most healthcare centers of developing countries face difficulties on the handling and management of clinical solid waste because of insufficient economic investment, lack of regulatory trained hospital staffs and specific materials (i.e., Color coded plastic bags, waste bin) for separation of infectious wastes at the generation source. Effective sterilization technology to sterilize the clinical waste at the generation source is required. There are many advantages over the effective sterilization of clinical waste at the generation sources during initial collection, such as [5,8,24]

- Waste can be treated as non-clinical waste.
- Waste will be free from infectious pathogenic micro-organisms.
- Waste will not pose any threat for clinical staff and hospitals environment.
- Handling of clinical waste during collection, storage and transportation will be carried out by non-specialized clinical staff.
- Segregation and classification of waste will be carried out at the point initial collection by non-specialized clinical staff.
- Recycling-reuse program of clinical waste will be carried out successfully.

9. SUPERCRITICAL FLUID CARBON DIOXIDE STERILIZATION

The definition of the term ‘sterilization’ is the complete destruction or removal all living microorganism on or within a substances, including bacteria or spores, viruses and fungi. [26,27,28] The most common sterilization techniques used are steam autoclaving, ethylene oxide and ionizing radiation. Though, all these methods assure a satisfactory microbial inactivation, but have a number of limitations. Furthermore, all these techniques
are very expensive and difficult to manage and control because of the extremely high temperature and pressure required. Therefore, above sterilization method are not suitable for the sterilization of clinical solid waste, since the heat sensitive reusable waste materials may destroy with the high temperature. Hence, it is bearing urgency to determine low temperature sterilization technology, where supercritical fluid (SCF) sterilization technology is highly promising.\[29\]

SCF is any compound at a temperature and pressure above the critical values (above critical point). Above the critical temperature of a compound the pure, gaseous component cannot be liquefied regardless of the pressure applied. The critical pressure is the vapor pressure of the gas at the critical temperature. In the supercritical environment only one phase exists. The fluid, as it is termed, is neither a gas nor a liquid and is best described as intermediate to the two extremes. This phase retains solvent power approximating liquids as well as the transport properties common to gases. Like a gas the SCF shows lower viscosity and higher diffusivity relative to the liquid. These properties facilitate mass transfer phenomena, such as matrix extraction or impregnation. Like a liquid, the SCF shows density of a value high enough for exerting salvation effects. A SCF is dense but highly compressible, thus, any pressure change results in density alteration and, consequently, in solvent power variation. In the vicinity of the critical point, the compressibility is high, and a small pressure change yields a great density modification.\[28\] A comparison of typical values for density, viscosity and diffusivity of gases, liquids, and SCFs is presented in Table 4.

**Table 4: Comparison of physical and transport properties of gases, liquids, and SCFs\[31\]**

<table>
<thead>
<tr>
<th>Property</th>
<th>Density (kg/m$^3$)</th>
<th>Viscosity (cP)</th>
<th>Diffusivity (mm$^2$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>1</td>
<td>0.01</td>
<td>1–10</td>
</tr>
<tr>
<td>SCF</td>
<td>100–800</td>
<td>0.05–0.1</td>
<td>0.01–0.1</td>
</tr>
<tr>
<td>Liquid</td>
<td>1000</td>
<td>0.5–1.0</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Several SCFs have been used in both commercial and development processes, of which the most commonly used carbon dioxide (CO$_2$). CO$_2$ has been widely uses SCF due to many advantageous features such as\[30\]

- effective against microorganism,
- low critical parameters (31.1°C, 73.8 bar),
- low cost and non-toxicity, non-flammable,
- available in abundance, recyclable, environment friendly.
Since the critical values of pressure and temperature are relatively low, the gas is relatively easy to handle under supercritical conditions.

SF-CO$_2$ presents high dissolving power, high diffusivity and low viscosity for the microbial inactivation makes it widely used in supercritical fluid sterilization technology.

SF-CO$_2$ is effective against any sort of micro-organisms, as it impacts target micro-organisms both physically and chemically.

10. CONCLUSION

In this review, existing clinical solid waste management practices has been investigated to determine appropriate management technology for the management of clinical solid waste in healthcare centers.

The main priority has been given on the handling and disposing of clinical solid waste by taking into consideration both infectious risk and economic factors. It is observed that the generation of clinical solid waste has been increasing due to the wide acceptance of single-use disposable items. The existing waste management practices, particularly in third world countries, are considered as inadequate.

This review study reveals a serious need to adopt effective sterilization technology in management of clinical solid waste prior to final disposal. Hence, adopting the supercritical fluid carbon dioxide sterilization to sterilize the clinical solid waste at the point of initial collection is highly recommended to prevent infection and contamination.

Consequently, waste would not bear any infectious risk and therefore, collection, segregation and recycling-reuse program of clinical solid waste materials can be carried out with non-skilled clinical staffs.

Accordingly, healthcare centers can provide a safe environment for the patients, healthcare staff and waste handlers. Furthermore, the adoption of SF-CO$_2$ sterilization technology in management clinical solid waste would reduce exposure to infectious waste, decrease labor, minimize the management costs, and yield better compliance with regulatory.

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