Suitable Options For Treatment And Disposal Of Hazardous Health Care Waste

Supported by:

World Health Organization (WHO)

Nepal Health Research Council
Ramshah Path, Kathmandu
June 2004

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Submitted To
Nepal Health Research Council

Submitted by:

Vikram Basyal - Team Leader
Waste Management / Environmental Health Expert

Dhiraj Pokhrel
Socio Economist

Contents

Abbreviations & Acronyms

AIDS	Acquired Immune Deficiency Syndrome
BOD	Biological Oxygen Demand
BPKIHS	B.P Koirala Institute of Health Science
CCD	Polychlorinated dibenzo-p-dioxins
CDF	Polychlorinated dibenzo-furans
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
ENPHO	Environment & Public Health Organisation
ENT	Ear Nose Throat
GOI	Government of India
HC	Health Care
HCI	Health Care Institution
HEPA	High Efficiency Particulate Air
ICU	Intensive Care Unit
KMC	Kathmandu Metropolitan City
LTSF	Low Temperature Steam Formaldehyde
NEERI	National Environmental Engineering Research Institute
NHRC	Nepal Health Research Council
OPD	Other Patient Department
OT	Operation Theatre
PPMV	Parts per Million in Volume
PSI	Pounds per Square Inch
PVC	Poly Vinyl Chloride
SEF	Save the Environment Foundation
TEQ	2,3,7,8-Tetrachlorinated Dibenzo-p-dioxin toxic equivalent based on the 1989 international toxic equivalency factors.
TTS	Teku Transfer Station
UN	United Nations
WHO	World Health Organization

Acknowledgements

We are sincerely thankful to Dr. S.K Pahari, Chairman, NHRC; and Dr. Anil Kumar Mishra, Member-Secretary NHRC for allowing us to work on this topic.

We wish to express our deep sense of gratitude to Mr. Shamsul Huda Environmental Health Adviser, WHO for his kind suggestions.

We deeply indebted to Mr. Chandra Shekhar Yadav, Environmental Engineer, NHRC, who has been constant source of inspiration & guidance to us and for whom we feel deep rooted reverence in our heart.

Our grateful thanks to Mr. Salil Devkota Environmental expert for his kind suggestions.

We also wish to thank to Mr. Bidhya Nath Bhattarai, Ministry of Physical planning and works; Mrs. Ranjani Joshi, WHO & Mr. R.C. Shah, pro-public for providing us with vital subject matter & data.

We would like to thank Mr. Surya Man Shakya, General Manager; Solid Waste Management & Resource Mobilization Centre, for his valuable suggestions

Vikram Basyal-Team Leader
Waste Management / Environmental Health Expert
Jun, 2004

1.0 Introduction

Hospital waste management has become a serious concern in the nation. The government should have an adequate framework or structure in place to address the issue on a national level. Ministry of health and ministry of environment have the responsibility for promulgating practical guidelines, standards or rules to assist health care facilities in the effective management of these wastes. In particular, hazardous hospital wastes, when ineffectively managed, may compromise the quality of patient care. Additionally, these wastes present occupational health risks to those who generate package, store transport, treat and dispose them. They also present environmental and public health risk through inappropriate treatment and or disposal which may contribute to environmental pollution and the spread of infectious diseases such as AIDS, hepatitis, tuberculosis, cholera, diphtheria and many others. This concern is heightened by the appearance of new and emerging pathogens as well as by the re-emergence of drug resistant ones. The management of wastes arising from health care facilities is thus an integral part of the country's health systems.

This study report book recommends safe, efficient, sustainable, affordable and culturally acceptable methods for the treatment and disposal of health care waste, both within and outside health care establishments.

This afford aims not only to promote a sound managerial approach and the use of appropriate technologies, but also to inform the country about the health risk that result from inadequate management of health care waste.
Health care waste management as well as poising technical problems, is strongly influenced by cultural, social and economic circumstances. A well designed waste policy, a legislative frame work and plans for achieving local implementation are essential. Change will be gradual and should be technically and financially sustainable in the long term.

1.1 Background

Every year, large quantities of hazardous and non hazardous wastes are produced by hospitals and other health care centers in the country. These health care center's waste management systems are worsed due to lack of commitment and dedication by managerial position, inforcing laws as well as in some extent by the lack of financial resources and trained manpower.

Hardly, few individuals on a hospital's management staff are familiar with the element of proper waste management. In all most all private and government hospitals, waste handling is left to the poorly educated and lowest category of workers, operating without any training, guidance and supervision. Hospitals have no government guidance for waste management. Often hazardous wastes are mixed with municipal wastes and deposited untreated in landfills.

1.2 Objective of the study

The primary objectives of the study are:

1. Identify the actual condition of the HC waste management system in the nation.

2. Analyse the available waste treatment and disposal methods.
3. Analyse policies & legal situation
4. Propose appropriate options for the treatment & disposal of waste.

1.3 Scope of the study

The scope of the study includes

1. Evaluation of present hazardous HC wastes management practice.
2. Evaluation of risk related with improper HC waste management.
3. Identification of technical aspects of waste management.
4. Aware public & related persons.
5. Highlight the legal provision on HC waste management.
6. More clarify about different treatment options.

1.4 Methodology

1. Review of existing hazardous waste management system.
2. Review of National & International Publication.
3. Comprehensively assess the available different treatment & disposal methods available.
4. Carry out cost benefit analysis.
5. Review existing lows & regulations regarding the health care waste management.
6. Summarized to the best suitable treatment and disposal options.
7. Bir Hospital for specific study.

1.5 Limitation of the study

It is a study of existing waste management system and related publication. The purpose of the study is specifically towards treatment and disposal options. This study analyses only the published and unpublished informations and available technologies regarding proper management of hazardous health care waste.

Suitable options for treatment and disposal of hazardous HCW. W.H.O

2.0 General Situation of Waste Management

2.1 HC Waste management in Kathmandu valley

Kathmandu valley consists approximately 61 health care institutions with 3905 beds. Among them 3541 beds are located in Kathmandu city. And approximately 1312 kg of infectious waste is being produced in Kathmandu valley and 1189 kg/day in Kathmandu city (ENPHO, 2000). The composition of hospital waste generated in Kathmandu valley consists 62% non-infectious waste, 23% infectious waste, 3% sharps and 12% saline bottles. Most of health care institutions provide each bed with a bucket for waste collection. But it is seen that 54% of public hospital and 26% of private hospitals practice uncovered waste collection bins. In most of the health care centre, the safety aspect of handling of medical waste is ignored. The waste generated from government and private sector are collected, transported and disposed together with municipal waste on the bank of Bagmati river, (See Annex I)

Some facts and figures

- Infectious waste generation rate is 0.48 kg/person/day.
- Total waste generation rate is1.7 kg/person/day.
- Total infectious waste in Kathmandu city is1189 kg/day and in whole valley 1312 kg/day.
- It is expected that the infectious waste generation rate will increase by an amount of 81 kg/day.
- Total number of beds is increasing with an annual average growth rate of 5.38% and hence by the time of 2010, the total hospital beds will be 6593, which will result in more production of waste.
- Total number of known incinerator in Nepal is 24 and within Kathmandu valley, it is 13 (ENPHO, 2000).

2.2. HC Waste management in other parts of the country

Nepal's public health sector consists of five national hospitals, nine teaching hospitals, one regional hospital, and eleven hospitals at zonal or sub region and district level hospitals. According to Department of health services, there are 74 hospitals, 172 primary health care, 710 health posts and 3132 sub health posts in Nepal. Apart from these, numbers of private health institutions are established in the country. Increasing number of health care institutions all over the country are generating huge amount of waste. A total number of 6,521 hospital beds in Nepal are generating about 500 tones of hazardous waste per year (Tuladhar 1999).

(i) Dharan

BP Koirala Institute of health science has a capacity of 646 beds with a flow of around 585 patients per day. The volume of waste generated is about 250 kg per day. The amount of non- infectious waste generation per day is 186.7 kg which is treated as ordinary waste. The hospital generates 63 kg of infectious waste per day, which is incinerated before disposal. The hospital has 10-ton capacity incinerator with 2 manpower and the cost of incineration is about Rs. 25 per kg of waste. The quantity of waste is summarized in table 2.1

Table 2.1: Waste production in BP KIHS per day in kilograms

Type of waste	OT & Wards	Lab	OPD	Blood Bank	Emergency	Total
Non. Infec.	150-2	5.7	11.9	6.1	12.8	186.7
Infectious	57	6	-	-	-	63

Source: In charge Hospital Waste Management Committee BPKIHS

(ii) Biratnagar

There is a steady increase in the number of Health care centers in Biratnagar. The amount and type of medical waste generated is also increasing, but due to lack of proper medical waste management, the waste produced is being disposed haphazardly. About 3% of the total waste generated consists of sharps, 28% hazardous waste and 69% general waste. Generally, all the waste of wards and OPD is considered as non-infectious waste and mixed together and dumped at roadside dumping places, and municipality finally collects it. The waste from pathology and operation theatres are collected separately and buried at Singhiyahi riverbank by the sweeper of health care centers. General waste description of various Health Care Centres of Biratnagar are given in table 2.2

Table 2.2: Major HCI and waste Generated.

S.No.	Name of Health Care Institutions	No. of Beds	General waste	Hazardous waste	Sharp waste	Total (Kg/day)
1	Koshi Zonal Hospital	200	241	88	10	340
2	Birat Nursing Home	45	54	20	2	77
3	Purwanchal Medical Research Center	16	19	7	1	27
4	Abadh Narayan Memorial	14	17	6	1	24
5	M.J. Nursing Home	114	17	6	1	24
6	Fertility Center	15	18	7	1	16
7	Moran Cooperative Hospital	10	12	4	1	17
8	Ramlal Golcha Eye Hospital	50	60	22	3	85
9	Koshi Nursing Home	2	2	1	0	3
10	Neuro Diagnostic & Research Center	10	12	4	1	17
11.	Pathalogical Labs & Clinics	-	50	50	0	50
12.	Total waste generated	376	504	216	20	739

Source: Pro Public, 2003

(iii) Pokhara

Some major hospitals like Manipal Teaching Hospital, Gandaki Zonal Hospital and INF Leprosy hospital have the locally manufactured incinerators and are poorly maintained and operating. The segregation practice is not found satisfactory. Other small private sector health care centers have given contract to the private operators to collect all the medical waste, which is mixed with municipal waste and dumped, into Seti River near China Bridge.

The overall sanitation of Manipal hospital is good. A small local incinerator located in Manipal hospital is not sufficient to incinerate all the amount of infectious waste generated in the hospital. The ash produced from this incinerator is disposed in the Seti River.

Similarly the waste management system of Gandaki Zonal Hospital is also very poor. Waste is not segregated and burnt in locally manufactured incinerator. The Leprosy hospital has installed an incinerator including a big sized waste pit. The operation part of the incinerator has handed over to a private party and functioning well.

(iv) Nepalgunj

Mixed types of medical waste management have been observed in Nepalgunj. There is lack of onsite separation, lack of sanitation. All type of waste is mixed together and mostly disposed off on municipal waste collecting center near by the hospital. Bheri Zonal Hospital has one locally manufactured brick made incinerator, which is now out of function and in danger position to fall down.

(v) Kavre

Dhulikhel Hospital has constructed a low temperature incinerator for solid waste incineration. Since the incinerator is built at the lower level of hospital land, the smoke produced is polluting the hospital complex. The hospital has constructed a wastewater treatment plant with the support of a research organization and is functioning very well.

or radioactive wastes, PVC plastics, waste with mercury or cadmium content should not be treated by incinerators.

Incinerators can range from extremely sophisticated, high-temperature operating plants to very basic combustion units that operate at much lower temperature. All types of incinerators if operated properly, eliminate pathogens from waste and reduce the waste to ashes. However, certain types of health care wastes e.g pharmaceutical or chemical wastes require high temperature for complete destruction.

Basically, there are following three types of incinerator used for treating health-care waste:

- Double chambered pyrolytic incinerator
- Single chambered furnaces
- Rotary kilns

I. Pyrolytic Incinerators

The most reliable and commonly used treatment process for health-care waste is pyrolytic incineration, also called controlled air incineration or double chambered incineration" (Pruss et. al... 1999). This type of incinerator consists of two chambers: pyrolytic chamber and post combustion chamber.

In the pyrolytic chamber, the waste is combusted producing ashes and gases at a temperature ranging between 800-900^0 C. Gases produced from the combustion are burned in the post combustion chamber at a temperature between 900-1200^0 C, reducing its toxicity before mixing with the ambient air.

Although incineration is widely used all over the world, one of the main concerns regarding its use is the potential for emitting harmful gases. Particularly dioxins and furans, which are considered to be carcinogenic. Optimal combustion conditions are essential for complete destruction of waste without generation of significant amount of harmful gases. Pyrolytic incinerators should therefore meet the following condition (Pruss et. al... 1999):

- The three "T" (temperature, time and turbulence) principles should be followed. In the post-combustion chamber gas should be exposed to at least 900^0 C for at least 2 seconds, and air inflow with 100% excess oxygen and high turbulence should be ensured.
- The pyrolytic chamber should allow the residence time of 1 hour for the waste.
- Both the chambers should be made of steel with an internal lining of refractory bricks, resistant to corrosive waste or gas and thermal shock.
- The feed opening should be large enough for loading packed waste.
- There should be provision for collecting the ash and cooling it before disposal.
- The incinerator should be operated, monitored and regulated from a central console, which should include a continuous display of temperature, air flow and fuel flow.

The pyrolytic incinerator should be operated and monitored by a well trained technician who can maintain the required conditions, controlling the system manually if necessary. Correct operation is essential, not only to maximize treatment efficiency and minimize the environmental impact of emissions, but also to reduce maintenance costs and extend the life expectancy of the equipment. A careful operational balance needs to be maintained between the two combustion chambers (See Annex II).

II. Rotary Kiln Incinerator

A rotary kiln incinerator consists of a rotating oven and post-combustion chamber. It is most suitable for treatment of chemical waste and can also be used for infectious and pathological waste. The rotary kiln is inclined at slight angle to the vertical, which rotates to 2 to 5 times per minute. Waste is fed from the top and ashes are accumulated at the bottom. The operating temperature is 1200 to 1600° C, which is higher than that of pyrolytic incinerators. As a result, these types of incinerators are more expensive and consume more energy. Gases produced in the kiln are burned in the post-combustion chamber and typically have a residence time of 2 seconds.

III. Single – Chamber Incinerator

In case where pyrolytic incinerator is unaffordable, single-chambered incinerator can be used. These incinerators have one chamber with a static grill where waste is burned by adding some fuel. Air inflow is usually through natural ventilation and the temperature inside the incinerator reaches up to 400° C.
Single chambered incinerators can also be made locally by using a drum or by brick/concrete. The efficiency of these types of incinerators may reach 80-90% and result in 99% destruction of micro-organisms and significant reduction in weight and volume. However, many chemical wastes will persist if temperatures do not exceed 200° C. (Pruss, et. al… 1999).

Although this type of incinerator is usually cheap to construct and operate, the gases emitted by this incinerator usually consists of sulphur dioxide, hydrogen chloride, hydrogen fluoride, black smoke, fly ash, carbon monoxide, nitrogen oxide, heavy metals and volatile organic chemicals.
This type of incinerator can be used for infectious and pathological waste and also for general waste. Pharmaceutical and chemical waste, genotoxic waste, radioactive waste and inorganic compounds and thermally resistant waste cannot be treated. Categories of waste that should not be treated in single-chambered incinerator are the same as for pyrolytic incinerator.

Advantages of Incinerators

Advantages of using incinerators for treating medical waste are as follows:

- It reduces the mass and volume of waste.
- It adds aesthetic value as it destroys the organic components of the waste which is often objectionable to public.
- It causes destruction of infectious organism.
- It prevents unauthorized recycling.
- It avoids contact with recognisable items by general working force.
- It has ability to manage most types of waste with little processing before treatment.
- Reliable & fully commercialized technology.

Disadvantages of incinerators

- It emits potential source of air pollution. As such it must comply with instructions of pollution control standard.
- Increased cost of incineration, high cost of installation, operation, repair and maintenance of equipment need to be defined by new emission.
- Increased awareness of environmental pollution and health impact of incinerator by particulate emission and acid gases.
- Formation of dioxins and furans with increase of PVC chemicals is particularly dangerous.
- Low quality incinerator could cause air pollution.

Waste that should not be incinerated

- Pressurised containers
- Halogenated Plastics such as PVC
- Waste with heavy metal content
- Radio active waste
- Genotoxic waste

Wastes that can be incinerated

- Infectious waste, sharps and pathological waste
- Pharmaceutical and chemical residues
- General health care waste.

3.1.2 Autoclave

This is low heat thermal process, which is designed to bring steam into direct contact with the waste in a controlled manner for a sufficient duration to disinfect the waste. This was originally introduced outside the arena of biomedical wastes, and has been used since a long time for the sterilization of reusable medical instruments and microbiological laboratory cultures and stock solutions. The first instance when autoclave was put to use for sterilization of medical waste was in 1978 in California, USA. (See Annex III)

Operational Aspects

- The infectious wastes and bags are placed in sealed, pressurised chamber and exposed to open steam at required temperature (depending upon the type of autoclave) for a specific holding time (which is also fixed for different types of autoclave). The most important thing to note here is that the proper temperature, pressure and holding time correlation is matched, in order to achieve desired level of sterilization.
- As a rule of thumb, all infectious waste is recommended to be treated at *121^0 C for a holding time of 30-60 minutes*. After treatment it reduces the volume by minimal amount, with plastic materials melted and disfigured.
- To monitor the efficacy of the treatment process and to see the destruction of all micro-organisms has taken place, spores of *Bacillus stearothermophillus* can be placed at the centre of waste load, and checked.

Steam autoclave treatment systems should be serviced according to the maintenance schedule recommended by the manufacturer (See Annex IV). While the types of systems vary widely, mainly similarities exist. All autoclaves have a tightly sealed treatment chamber and drains that must be cleaned and inspected on a regular basis. They all have temperature and pressure gauges used to monitor treatment parameters that must be validated. Steam supply lines and condensation lines are present in most systems.

Advantages

1. Low capital and operating costs as compared to other treatment options.
2. Low level of skills required for operators.
3. Liquid emissions are minimal.
4. Air emissions are not toxic/hazardous.
5. Environment friendly technology

Disadvantages

1. Medium efficacy for sterilization which implies some microorganisms may still be thriving
2. There occurs partial reduction in waste volume and some plastic materials tend to melt and get disfigured. Non-plastic wastes are still recognizable hence landfilling, etc. is difficult.
3. Certain categories of waste *viz.* pathological, cytotoxic and other toxic waste cannot be treated through this method.
4. Odorous fumes create problems which need to be controlled by putting odour control tablets.
5. "Batch Operation" System involves manual loading and removal of waste from the autoclave, hence there is chance of infections.

5.1.3 Hydroclave

This is a low heat thermal process which is an innovation of the autoclave designed to apply steam as an indirect heating source, allowing total dehydration of the waste. In addition, the waste is also internally agitated and fragmented to attain high degree of sterilization of all waste components and particles. The first prototype hydroclave invented by Richard Vanderwal was put into operation at Kingston General Hospital, a large teaching hospital in Ontario, Canada processing about 450 Kg of biomedical waste per day.

It is essentially a double walled cylindrical vessel, horizontally mounted, with one or more top loading doors, and a smaller unloading door at the bottom. The vessel is fitted with a motor driven shaft to which are attached powerful fragmenting mixing arms that slowly rotate inside the vessel.

When steam is introduced into the vessel jacket, it transmits heat rapidly to the wet fragmented waste, which, in turn produces steam of its own. This causes the waste to be fragmented and continuously tumbled against the hot walls by the fragmenting arms. The moisture content of the waste turns into steam and the vessel starts to pressurize. In the absence of adequate moisture in the waste to pressurize the vessel, a small amount of steam is added until the desired pressure is reached. The treatment/holding time is 15 minutes at 132 $^{\circ}$ C or 30 minutes at 121° C to achieve sterilization. The dynamic interaction by hydrolysis the organic components of waste and reduces volume (upto 85%) and weight (upto 60%), besides allowing self unloading after the treatment cycle.

Advantages

1. No pretreatment of waste is required as the fragmenting and mixing mechanism is available inside the hydroclave.
2. Complete waste dehydration during the sterilization process, which can help in the long run, as transportation and landfilling costs will be decreased.
3. Volume and weight reduction is achieved to a great extent thus reducing the landfilling requirements.
4. Operator maintenance skills are required to be of low level, as it is a simple electromechanical device with "push button" operation.
5. Both capital cost and operating cost are low, as it uses steam which is practically the least expensive source of energy.
6. Environment aspect – Air emissions may be somewhat odorous but are generally not-toxic; and water emissions are minimal, odorous but sterile. It can also hydrolyse segregated, organic waste to a homogenous substance ready for use as a soil supplement; and two hydroclaves (one for organic waste, other for hospital waste) could be put into use tandem at hospitals or municipal landfills.

Disadvantages

1. The air emissions are odorous which could cause problems during the operation of the machine.
2. The sterilization efficacy is not as complete as it is during incineration.
3. Certain types of waste i.e. pathological, cytotoxic and other toxic wastes cannot be treated with this.
4. However, it seems that some of the problems that were evident in the autoclave have been removed by this treatment option, although shredder might be required to shred the output of hydoclave, before landfilling. This method requires more precautionary measures than autoclave and is not approved by the Central Pollution Control Board in India till 2000. So there is a need of further study before adopting this method.

3.1.4 Microwave

This is a low heat thermal process with a difference, in the sense that unlike other low heat processes which heat the waste from outside; this heating occurs inside the waste material. Microwaves are electromagnetic waves that enter into or penetrate materials. It is that portion of electromagnetic radiation spectrum, lying between 300 and 300,000 mega hertz. When exposed to microwave energy, all dipole molecules of a mass are put to vibration, which produces friction. This friction of vibrating molecules produces heat which results in disinfection. The microwave technology originated in Germany in the early 80's and the first unit was installed at Forsyth Memorial Hospital in Winston-Salem, North Carolina in 1990. Subsequently, this has been gaining ground and has been approved for a number of States of USA, Canada, Brazil and Europe. It has also been approved by the Central Pollution Control Board in India.(Anand , RC et.al 2000)

The Principle on which microwave operates is by energizing the water (dipole) molecules, so that substance gets heated from inside the mass. The next step involves the movement of wastes in a screw auger which is heated to about 95° C to 100° C by a number of conventional microwave generators, arranged in series, to ensure continuous turning of waste material. Maintenance of this temperature for a holding time *of 25* minutes ensures that all microorganisms (i.e. bacteria, spore, parasites, fungi and virus) are killed.

There is no decomposition of materials thereby, both liquid and gaseous emissions are eliminated. The inside air is treated with high pressure steam and discharged through HEPA and Carbon filters which eliminate potentially hazardous airborne pathogens. A microprocessor control maintains the time temperature interaction for complete disinfection of the waste and alerts the operator when to feed more waste into the unit. Additional features include computer aided reports attached to microwave device, which confirm total disinfection by providing temperatures achieved in the chamber along with duration of heating.

Treatment of infectious waste like syringes, needles, tubings, dialysis etc. in a microwave device, makes it harmless and unusable. They are discharged as unrecognizable materials with a volume reduction of up to 80% without any reduction of weight. These can be discharged as household wastes. Once treated, the waste is dry and can be landfilled or recycled after classification for recyclables such as plastic, metals, glass and organic constituents for composting. It can be tested by appropriate biological indicates, e.g. spores of Bacillus.

Advantages

i. Although disinfection technology is similar to autoclave (i.e.with heat)the process is not batch operated but continuous with aromatic removal of product for disposal. It is a more mechanical and automated process, with less manual work.
ii. Characteristics of treated waste is acceptable for land filling as it has been rendered unrecognizable, with volume reduction up to 80%, even though there is no weight reduction.
iii. Environmental aspect-Air emissions are somewhat odorous, but non-toxic, whereas water emissions are negligible. No pollution hazards are associated with this.

Disadvantages

i. Microwave as a disinfection system requires a shredder prior to putting the waste, so that they are sterilized more evenly and quickly.
ii. It is not able to penetrate large and device objects like-amputated limbs, tissues, specimens, etc. which are part of anatomical waste.
iii. High cost technology – Both the capital cost and operational cost for microwave is quite high.
iv. Operator skills- Since the process is largely automated, one requires a skilled operation for proper operation.
v. There is potential for release of volatile material from the process.
vi. Microwave cannot be used for cytotoxic, hazardous or radioactive wastes, and large metal pieces.

3.1.5 Chemical disinfections

Disinfections are defined as the "process by which most of the pathogenic microorganisms are destroyed from any inanimate body, surface or material". When this is done by chemical means, it is known as chemical disinfection. Hospital wastes in the category of "infectious wastes" should be disinfected prior to final disposal.

Application

- Instruments and equipments that come in contact with skin, mucus membrane, skin piercing instruments.
- Infected sharps like needles, tubings, syringes, etc.
- Contaminated instruments and equipments.
- Contaminated floors, surfaces like trolley tops, table tops, trays, clothes, beddings, beds, crockery, enamel, stainless steel, bed pan, etc.
- Wards, OTs, ICUs from time to time.

Common chemicals used for disinfections

- Bleach 1% solution for disinfection of materials contaminated with blood/body fluids.
- Bleaching powder-for toilets, urinals, bathrooms, etc.
- Methylated spirits (70%) – for disinfecting surfaces on which bleach cannot be used, e.g. smooth metal surfaces, table tops etc.
- Alcoholic hand wash (70%) –Methyl alcohol to which 1% glycerine is added, available in all clinical settings.
- Glutaraldehyde (2%) – Cidex for disinfection of surfaces and instruments, that are destroyed by bleach, changed after 14 days.
- Detergent with enzyme –for cleaning endoscopes, theatre instruments and obstetric instruments before disinfection.
- Savlon 1% -for cheatle forceps.

3.2 Disposal of waste

It is the final step of management of health care waste after or without treatment. Disposal is the process of burial, discharge, deposit, dumping, land-filling or placing on land of any waste after treatment of their infectious and hazardous nature. According to National Health Care Waste Management Guidelines of NHRC, there are four types of disposal options.

3.2.1 Sanitary landfill

An engineered method designed to keep the waste isolated from the environment. Appropriate engineering preparations should be completed before the site is allowed to accept waste. There should be a trained staff present on site to control operations, organized deposit and daily coverage of waste. Some essential elements for the design and operation of sanitary landfill.

- Access to site and working areas possible for waste delivery and site vehicles
- Presence of site personnel capable of effective control of daily operations.
- Division of the site into manageable phases, appropriately prepared, before landfill starts.

- Adequate sealing of the base and sides of the site to minimize the movement of wastewater (leachate) off the site.
- Adequate mechanisms for leachate collection, and treatment systems is necessary
- Organized deposit of waste in a small area, allowing them to be spread, compacted and covered daily.
- Surface water collection trenches around site boundaries construction of a final cover to minimize rainwater infiltration when each phase of the landfill is completed.

3.2.2 Encapsulation

Disposal of health-care waste in municipal landfills is less advisable if it is untreated than if it is pretreated. One option for pretreatment is encapsulation, which involves filling containers with waste, adding an immobilizing material, and sealing the containers. The process uses either cubic boxes made of high-density polyethylene or metallic drums, which are three- quarters filled with sharps and chemical or pharmaceutical residues. The containers or boxes are then filled up with a medium such as plastic foam, bituminous sand, cement mortar, or clay material. After the medium has dried, the containers are sealed and disposed of in landfill sites.

This process is relatively cheap, safe, and particularly appropriate for establishments that practise minimal programmes for the disposal of sharps and chemical or pharmaceutical residues. Encapsulation alone is not recommended for non-sharp infectious waste, but may be used in combination with burning of such waste. The main advantage of the process is that it is very effective in reducing the risk of scavengers gaining access to the hazardous health- care waste.

3.2.3 Safe burial

In remote locations and rural areas experiencing exceptional hardship, the safe burial of waste on the health care premises may be the only viable option available at the time. However, certain rules should need to be established by the healthcare management:

- Access to the disposal site should be restricted to authorized personnel only.
- The burial site should be lined with a material of low permeability, such as clay, if available, to prevent pollution of any shallow groundwater that may subsequently reach nearby wells.
- Only hazardous healthcare waste should be buried. If general healthcare waste were also buried on the premises, available space would be quickly filled-up.
- Large quantities (>1 kg) of chemical/pharmaceutical wastes should not be buried.
- The burial site should be managed as a landfill, with each layer of waste being covered with a layer of earth to prevent odor, as well as to prevent rodents and insects proliferating.
- Burial site should not be located in flood frown areas.
- Hospital ground should be secured.(e.g. fenced, warning signs)
- The location of waste burial pit should be downhill or down-gradient from any nearby wells and about 50 meters away from any water sources such as rivers or lakes to prevent contaminating sources of water.
- Healthcare facilities should keep a permanent record of the size and location of all their on-site burial pits to prevent construction workers, builders, and others from digging in those areas in the future.

The safe burial of waste depends critically on rational operational practices. The bottom of the pit should be at least 1.50 meters higher than the ground water level. It should be noted that safe on-site burial is practicable only for relatively limited period, say 1-2 years, and for relatively small quantities of waste, say up to 5 to 10 tons in total. Where these conditions are exceeded, a longer-term solution will need to be found.

3.2.4 Inertization

Especially suitable for pharmaceutical waste, is the process of inertization that involves the mixing of the waste with cement and other substances before disposal. This is to minimize the risk of toxic substances contained in the waste migrating into surface water or groundwater. For the inertization of pharmaceutical waste, the packaging should be removed, the pharmaceuticals ground, and a mixture of water, lime and cement added. The homogenous mixture can be transported in liquid state to a landfill and poured into municipal waste. The process is relatively inexpensive and can be performed using relatively unsophisticated equipment. The following is the typical proportion for the mixture: 65% Pharmaceutical waste, 15% lime, 15% cement and 5% water. Table 3.1 gives other related features of different treatment methods.

Table3.1 Summary of main advantages and disadvantages of treatment and disposal options

Treatment/disposal method	Advantages	Disadvantages
Rotary kiln	Adequate for all infectious waste, most chemical waste and pharmaceutical waste	High investment and operating costs.
Pyrolytic incineration	Very high efficiency. Adequate for all infectious waste and most pharmaceutical and chemical waste	Incomplete destruction of cytotoxics. Relatively high investment and operating costs.
Single chamber incineration	Good disinfection efficiency. Drastic reduction of weight and volume of waste. The residues may be disposed of in landfills. No need for highly trained operators. Relatively low investment and operating costs.	Significant emissions of atmospheric pollutants. Need for periodic removal of slag and soot. Inefficiency in destroying thermally resistant chemicals and drugs such as cytotoxics.
Drum or brick incinerator	Drastic reduction of weight and volume of the waste. Very low investment and operating costs.	Destroys only 99% of microorganisms. No destruction of many chemicals and pharmaceuticals. Massive emission of black smoke, fly ash, toxic flue gas, and colours.
Chemical disinfection	Highly efficient disinfection under good operating conditions. Some chemical disinfectants are relatively inexpensive. Drastic reduction in waste volume.	Requires highly qualified technicians for operation of the process. Uses hazardous substances that require comprehensive safety measures. Inadequate for pharmaceutical, chemical and some types of infectious waste.
Wet thermal treatment	Environmentally sound. Drastic reduction in waste volume. Relatively low investment and operating costs.	Shredders are subject to frequent breakdowns and poor functioning. Operation requires qualified technicians. Inadequate for anatomical, pharmaceutical, and chemical waste and waste that is not readily steam- permeable.
Microwave irradiation	Good disinfection efficiency under appropriate operating conditions. Drastic reduction in waste volume. Environmentally sound.	Relatively high investment and operating costs. Potential operation and maintenance problems.
Encapsulation	Simple, low-cost and safe. May also be applied to pharmaceuticals.	Not recommended for non-sharp infectious waste.
Safe burying	Low costs. Relatively safe if access to site is restricted and where natural infiltration is limited.	Safe only if access to site is limited and certain precautions are taken.
Inertization	Relatively inexpensive	Not applicable to infectious waste.

Source: WHO, 1999

4.0 Comparative Review

There are various types of treatment and disposal options available. They have their own merits & demerits. These alternatives are compared on the basis of the capital & operating cost, efficiency, environmental standard and level of commercialization of the technology. The treatment and disposal options are separately compared with their alternatives.

4.1 Treatment technologies

All the treatment technologies explained above have their own advantages and disadvantages. No single method is sufficient to the complete treatment and disposal of whole health care waste.

The table 4.1 below gives the relative advantages and disadvantages of the treatment technologies.

Table 4.1 Relative study of different treatment methods

Treatment Systems	Autoclave	Hydoclave	Microwave	Incinerator	Chemical
Description	Steam sterilization (direct heating)	Steam sterilization (indirect heating) simultaneous shredding and dehydration	Microwave heating of pre-shredded waste	High temperature waste incineration	Mixing pre-ground waste with chemical, such as chlorine
Sterilization efficacy	Medium	Medium	Medium	High(total destruction of micro organisms)	Dependent on chlorine strength and dispersment through the waste
Capital cost	Low	Low	High	High	Moderate
Operating cost	Low	Low	High	High	Low
Operator maintenance skills	Low skill level required	Low skill level required	Automated, but highly complex and high level maintenance skill required	High level operator and maintenance skill required	High level required for chemical control and grinder
Air emissions	Odorous but non toxic	Somewhat odorous but non-toxic	Somewhat odorous but non toxic	Can be highly toxic	Some chlorine Emissions
Water emissions	Odorous, may contain live micro-organisms	Odorous but sterile	Negligible	None	None
Treated waste characteristics	Wet waste, all material recognizabl e	Dehydrated, shredded waste unrecognizable material	Shredded but wet waste	Mostly ash, may contain toxic substances	Shredded wet waste, containing chemicals used as disinfectants.

Source: CPCB, Delhi, 2003

4.1.1 Incinerator

Although incinerator is not a satisfactory solution to the medical waste treatment, there is no substitution of its kind. No comparative technology with incinerator is found as it helps to reduce the mass and volume of waste to a great extent. The bad side of incinerator is its polluting nature. Regrettably, it has been reported that waste incinerators contribute 69% of the dioxins in the global environment. PVC products contribute as much as 80% of the total chlorine fed into the medical waste incinerators.
In the recent years, pollution control devices, such as wet and dry acid scrubbers are available for medical waste incineration. These devices remove or neutralize the acid gases. Other devices available include fabric filters (bath house), electrostatic precipitators, hybrid dry or wet scrubber and after burners.

To minimize the source of dioxins in the global environment, a number of approaches have been proposed:

(a) Minimize the use of PVC products in medical treatment processes.
This approach will be successful if cost effective alternative products are easily available. Nevertheless, the extensive use of PVC in medical treatment processes has been developed over a long period of time. The special properties of PVC should not be dismissed without due consideration.

(b) The use of high-temperature incinerators
Chemical reaction equilibrium favours the formation of dioxins and dioxin-like chemicals at the regular operating temperatures (400-800 degrees C) of most waste incinerators. Recently developed high- temperature incinerators include the Canadian "Eco Waste Oxidizer" which has been successfully installed in the Kauai Veteran's Memorial Hospital in Hawaii (See Table 4.2). The "Eco Waste Oxidizer" uses a two-stage thermal oxidation system and a scrubber to treat the off-gases from the second stage burner. In the first stage, waste is ignited in the combustion chamber by means of a gas, propane or oil fired burner. Off gases from the first (burning) stage are re-burned in the second stage after burner chamber at 1000 degrees C and then emitted via a stack. The following emission standards were verified in tests conducted for the Ontario Ministry of Environment:

Table 4.2: Test Performance data of Eco-Waste Incinerator for Treatment of Medical Wastes

Selected contaminant	Eco Waste Incinerator Calculated Emission Concentration ug³	Ministry of Environment (MOE) of Ontario Standard Guideline Concentration ug³	Eco Waste Emissions as a Percentage (%) of the MOE Standards or Guidelines %
Particulate matter	6.55	100	6.55
Hydrogen Chloride	1.66	100	1.66
Nitrogen Chloride	16	500	3.2
Sulfur Dioxide	3.54	830	0.43
Cadmium	0.00016	5	0.0032
Lead	0.042	6	0.7
Mercury	0.00034	5	0.0068
Dioxins and Furans	2.9E-09	0.000015	0.019

Source: Emerging technologies and a sustainable hospital solid waste management system, 1999

Typical operating cost of the system was reported by the supplier to be US $0.40/kg versus the commercial hauling rate of US$0.70-0.90/ kg.

(c) Disposal by pyrolysis

Pyrolysis is another form of incineration under more stringent control of the incineration atmosphere. Current practice uses plasma to convey the energy intensity necessary to vaporize the medical waste. The gases are then oxidized under a controlled atmosphere. The volume of the waste is reduced by 90-95%. The temperature of oxidation is usually high enough to limit the formation of most dioxins. The high energy intensity required carries a relatively high capital and operating costs. The operating cost of such a system in Eastern United States was reported to be US$ 3.10/kg.

There are various types of incinerators available in the world. On the basis of the availability of t echnology, its cost & environmental standard, the pyrolytic incinerator is found most suitable (See table 4.3 & 4.5).

Table 4.3 Summary of main advantages and disadvantages of incinerators.

Treatment/disposal method	Advantages	Disadvantages
Rotary kiln	Adequate for all infectious waste, most chemical waste and pharmaceutical waste	High investment and operating costs.
Pyrolytic incineration	Very high efficiency. Adequate for all infectious waste and most pharmaceutical and chemical waste	Incomplete destruction of cytotoxics. Relatively high investment and operating costs.
Single chamber incineration	Good disinfection efficiency. Drastic reduction of weight and volume of waste. The residues may be disposed of in landfills. No need for highly trained operators. Relatively low investment and operating costs.	Significant emissions of atmospheric pollutants. Need for periodic removal of slag and soot. Inefficiency in destroying thermally resistant chemicals and drugs such as cytotoxics.
Drum or brick incinerator	Drastic reduction of weight and volume of the waste. Very low investment and operating costs.	Destroys only 99% of microorganisms. No destruction of many chemicals and pharmaceuticals. Massive emission of black smoke, fly ash, toxic flue gas, and colours.

Source: WHO,1999

Table 4.4: Incinerators suitable for different categories of health-care waste

Technology or Method	Infectious Waste	Anatomical Waste	Sharps	Pharmaceutical Waste	Cytotoxic	Chemical Waste	Radioactive Waste
Rotary kiln	Yes	Yes	Yes	Yes	Yes	Yes	Low-level infectious waste
Pyrolytic incinerator	Yes	Yes	Yes	Small quantities	No	Small Quantities	Low-level infectious waste
Single-chamber Incinerator	Yes	Yes	Yes	No	NO	No	Low-level infectious waste
Drum brick incinerator	Yes	Yes	Yes	No	No	No	No

Source: WHO,1999

Investment and operating costs

Capital costs for pyrolytic incinerators suitable for treating health-care waste vary widely. For illustrative purposes only, approximate costs of equipment available on the European market are given in Table 4.5.

Table 4.5: Approximate costs of pyrolytic incinerators (Europe)

Incinerator equipment	Investment costs (in 100 US$) for capacities (tonnes/day) of				
	0.4	1	2	4	8
Without energy recovery or gas cleaning	50	100	120	150	230
With energy recovery but without gas cleaning	100	180	230	340	570
With energy recovery and gas cleaning	300	400	480	600	780

Source: WHO, 1999

Examples of investment costs of various types and sizes of incinerators available in southern Asia are shown in Table 4.6.

Table 4.6: Investment costs for incinerators, southern Asia

Capacity	Equipment	Costs (US$)
50 kg/day	Manual loading, manual de-ashing, one combustion chamber, without flue-gas cleaning	20000
100 kg/day	Manual loading and de-ashing, secondary combustion chamber (temperature>1000 °C, residence time > 1s), without flue-gas cleaning	20000
100 kg/hour	Mechanical loading and de-ashing, secondary combustion chamber (temperature > 1000 °C, residence time> 1s) without flue-gas cleaning	400000
200 kg/hour	Automatic loading, mechanical de-ashing, secondary combustion chamber (temperature>100 °C, residence time > 1s), with flue-gas cleaning	800000
400 kg/hour	Automatic loading and de-ashing, secondary combustion chamber (temperature > 1000 °C, residence time >2s), with flue-gas cleaning and emission monitoring	1700000

Source: WHO, 1994

4.1.2 Autoclave and Microwave

These two technologies are based on same phenomenon of low heat thermal process. Autoclave is well known technology in the country and microwave is comparatively less familiar. Microwave is popular in western countries (See Annex V). A comparative evaluation of all the related issues of both the treatment equipment based on west Bengal Health System Development Project is as follows.

Table 4.7: Faculty & infrastructural requirement

S. No.	Items	Microwave	Autoclave
1	Space requirement	Small. Closed. Well ventilated.	Slightly more than Microwave. Closed. Well ventilated.
2	Treated residue as an environment concern	Nothing such. Vent pipe exit hole on the wall. Water pump is required to raise the water pressure.	Nothing such. Vent pipe exit hole on the wall. Diesel tank need to be placed at a higher area.
3	Utilities required	Power, water, air exhaust	Power, water, air exhaust.
4	Consumables	Container (only of company brand). microwavable bag, deodorant, plotter pen, plotter paper.	HSD (Diesel), Autoclavable bag, water softener, Hansen (Jute) Cloth, deodorant, ink, printer paper grease.

Table 4.8: Environmental, social, safety issues

S. No.	Items	Microwave	Autoclave
1	Air emissions	Slightly more odorous. Deodorant is added automatically.	Less odorous. Deodorant needs to be added.
2	Treated residue as an environment concern	No shredding required.	No shredding required.
3	Public approval.	Acceptable.	Acceptable.
4	Potential hazards during routine operations.	Negligible. Operator shall use protective equipment.	Negligible. Operator shall use protective equipment.

Table 4.9: Technical & Performance criteria

S. No.	Items	Microwave	Autoclave
1.	Process capacity	60 litre, Total cycle time-45 minutes	130 liter, Total cycle time-60 minutes
2.	Limitation of waste type	All except anatomical waste, Cyto-toxic drugs.	All except anatomical waste, Cyto-toxic drugs.
3.	Acceptable load per cycle	15 kg (30 litre)	65 kg (130 litre)
4.	Weight change of decontaminated waste	Total weight increases (due to addition of water)	Not significant
5.	Volume reduction*	15%	20%
6.	Physical appearance of decontaminated	Recognizable	Recognizable

	waste		
7.	Disinfections efficacy	Achieves disinfections level at 98 degree centigrade (Microwave heating).	Achieves disinfections level at 135 degree Centigrade of 31 Psi (210 Kpa) (Steam disinfection)
8.	Meeting prescribed standard of GOI	Yes. Meets the standard with respect to Bacillus Subtilis.	Yes. Meets the standard with respect to Bacillus Stearo-theemophillus.
9.	Complexity of Operation	Simple. Full automation.	Comparatively complex (because of boiler).
10.	Requirement of operation skill	Simple. Microprocessor controlled.	Microprocessor controlled. Comparatively complex (because of boiler).
11.	Maintenance Skill	High-level maintenance skill is required. Microwave generator plates need replacement after sometime (approximately after three years)	Comparatively Simple. Routine boiler servicing is required.
12.	Maintenance of records	Only operations logbook is to be maintained.	Besides operation log book-boiler logbook also is to be maintained.
13.	Print out monitoring	Reading is little bit difficult (graph only).	Very simple (displays every steps).

Table 4.10 Economics:

S. No.	Items	Microwave	Autoclave
1	Cost of Equipment (ex-factory)	Rs. 42 lacks	Rs. 31 lacks
2.	Cost of operation per kg waste	Rs. 77/- (with amortization) Rs. 50/- (without amortization)	Rs. 16 (with amortization) Rs. 10.50 (without amortization)

The above study shows that autoclave is suitable than microwave because of the various reasons described above.

4.1.3 Chemical disinfections

Chemical disinfection is commonly used in medical centers to clean instruments, floors, walls, etc. This is the basic requirement for making different equipment and health care premises hygienic.The most often used chemical disinfecting agents are: aldehydes, chlorine compounds, ammonia salts and phenol compounds. A serious drawback of the above method is the potential risk of those chemicals having an adverse effect on human health and the environment. Ethylene oxide is absorbed in the waste's porous material,

and formaldehyde remains in the waste. Both those agents have carcinogenic properties. The gaseous chlorine, which has a low capacity for penetration, plus it contributes to the origination of new, often toxic compounds: trihalomethane, polichlorinated biphenyls. As a result, this method enjoys little popularity. The efficiency and speed of the process depend on the kind and amount of the chemical agent applied and the time and area of its contact with the waste, the process temperature, humidity, pH etc.
Costs depend first of all on the price and availability of disinfecting agents

4.2 Disposal Options

4.2.1 Sanitary landfills

Generally, the treated or untreated waste is colleted in same municipal container & deposited on municipal open dumpsite. If untreated hazardous waste is openly dumped, it will lead to acute pollution problems, fires and risk of disease transmission.

Sanitary landfill is scientifically advanced & safer technology. But it may be difficult to sustain such method due to technical & financial problems for many municipalities. As city like Kathmandu where huge amount of waste is generating everyday, it may be appropriate to choose sanitary landfill method for a long term management of waste.

4.2.2 Encapsulation

The process is appropriate for untreated hazardous waste, only for small quantity. Encapsulation alone is not recommended for non sharp infectious waste. It is not so practical for mass waste management. Frequent use of this method may become burden to manage itself the capsule, after some years.

4.2.3 Safe burial

It is comparatively cheaper & easy technology than any other disposal method. It is useful for different types of hazardous waste except radioactive & cytotoxic waste. Design of burial pit may be of different types.

4.2.4 Innertization

This process is not safe. It just reduces the risk of toxic substances to migrate in the environment. This method is not applicable for infectious waste. This method is comparatively less reliable and popular as there is a risk of hazards. Table 4.11 summarized the treatment options for various types of waste.

Table 4.11: Disposal and treatment methods suitable for different categories of health-care waste

Technology or Method	Infectious Waste	Anatomical Waste	Sharps	Pharmaceutical Waste	Cytotoxic	Chemical Waste	Radioactive Waste
Rotary kiln	Yes	Yes	Yes	Yes	Yes	Yes	Low-level infectious waste
Pyrolytic incinerator	Yes	Yes	Yes	Small quantities	No	Small Quantities	Low-level infectious waste
Single-chamber Incinerator	Yes	Yes	Yes	No	NO	No	Low-level infectious waste
Drum or brick incinerator	Yes	Yes	Yes	No	No	No	No
Chemical disinfection	Yes	No	Yes	No	No	No	No
Wet thermal treatment	Yes	No	Yes	No	No	No	No
Microwave Irradiation	Yes	No	Yes	No	No	No	No
Encapsulation	NO	NO	Yes	Yes	Small Quantities	Small Quantities	No
Safe burial	Yes	Yes	Yes	Small quantities	No	Small quantities	No
Sanitary Landfill	Yes	No	No	Small quantities	No	No	No
Inertization	No	No	No	Yes	Yes	No	No
Other Methods				Return expired drugs to supplier	Return expired drugs to supplier	Return unused chemicals to supplier	Decay by storage

Source: WHO, 1999

5.0 Proposed Treatment & Disposal Options

Health care waste treatment and disposal system of Nepal is in a preliminary phase. Although there are various types of technologies available in the world, no single method is sufficient to treat and dispose all the categories of wastes.

This study tried to identify some best suitable technologies for the country with considering following factors.

1. Capital and operating cost
2. Environmental Standard.
3. Efficiency
4. Availability and reliability of the technology.

The study concluded on the following integrated approach for the treatment and disposal of hazardous health care waste.

5.1 Pyrolytic Incinerator

Justification

I. Most commonly used & available method.

II. No other comparative methods are available as it reduces volume & identification of waste.

III. More cleaner advanced technologies are available with different types of pollution control equipment.

IV. The only one point mandatory for incineration is the segregation & avoide the pollution causing waste to the incinerator.

V. The most reliable & commonly used incinerator is pyrolytic incinerator.

VI. Off-site treatment with regional incinerator is suitable because of the following reasons:

   a) It helps to install advanced technological equipment, which helps to reduce the pollution problems.
   b) It is easy to monitor & exam for related authority or Govt. Unit.
   c) Location should be far from residential area with high altitude, which prevent residential pollution problems.
   d) Air dispersion rate of the site should be high & general wind direction should be favorable to install the plant.

VII. Example of installation of pyrolytic incinerator:

   a) All India institute of medical sciences, New Delhi - the biggest institute in South Asia.
   b) Safdarjung Hospital New Delhi - one of the famous Hospital of New Delhi.

5.2 Autoclave

Justification

I. Autoclave is more cheaper than microwave.

II. It is suitable for sterilization.

III. Easily available & popular in South Asia.

IV. Operation cost is low.

V. Environmentally sound.

VI. On-site treatment is suitable.

VII. Reliable and fully commercialized method.

5.3 Chemical Disinfections

Although this process is widely used in western countries, it is not popular in south Asia. This method is used only for basic disinfection of different equipment and health care premises of the country.

Justification

I. Commonly used in Health care centres to clean instruments, floors, walls etc.
II. Recommended for limited use.
III. There is no other substitution of chemical disinfections.
IV. It is well familiar and cheaper method for general treatment.
V. Easily available and simple method for treatment.

5.4 Sanitary landfill

It has a high risk to deposit hazardous health care waste without treatment to the municipal open landfill site. In such a situation, sanitary landfill is an appropriate solution for the big city like Kathmandu.

Justification

I. It is environmentally safe, technologically advanced & scientific.
II. It can cover the waste of whole city.
III. Geographically suitable for Kathmandu.
IV. It prevents contamination of soil, surface & ground water & limits air pollution, smell & direct contact with public.
V. If not possible at present other options can be used such as: Controlled dumping, engineered landfill etc.

5.5 Safe burial

This system varies from place to place. The shape & size of the pit may be different types according to the need.

Justification

I. Easy, safe & cost effective.
II. It is useful for maximum types of health care waste.
III. It is a familiar & acceptable method.
IV. Not much precautionary measures are needed.

5.6 Other small units

In spite of all the above methods, some small plastic shredder and sharps treatment unit can also be adopted to make waste management system more healthier.

1. Plastic shredder: This technology cuts the plastic waste (plastic bottles, syringes, IV sets etc.) into small pieces, thus ensuring that syringes and other plastic materials are rendered non-reusable in same form. It does not generate aerosol or droplet pollution.

2. Sharp treatment units: Occupation injuries from needles and syringes are problems facing all health care providers. Many health care workers suffer needlestick and other precutaneous injuries due to sharps.

   Medical Disposal Devices offer a small device to vaporize needles using a high-temperature oxidation process. The device can be mounted on a wall or operated on a countertop. A sensor automatically activates the device. A disposable cartridge can hold the residues of 2,500 to 3,500 needles. Its dimensions are 10" x 4-1/2" x 3-1/2 and it weighs about 7-1/2 pounds. The cost of the unit is around $600. Similarly, there are various types of technologies are available for the treatment of sharps.

6.0. Environmental Requirements & Standards

There should be specified environmental standards for different waste treatment options. Nepal has not established such standards. In this situation the Indian standards for treatment & disposal of bio-medical waste can be followed. Which is as follows

Standards for Treatment and Disposal of Bio-Medical Wastes

STANDARDS FOR INCINERATIONS

All incinerators shall meet the following operating and emission standards:

A. Operating Standards

1. Combustion efficiency (CE) shall be at least 99.00%
2. The combustions efficiency is computed as follows:

$$CE = \frac{\%CO_2}{\%CO_2 + \%CO} \times 100$$

3. The temperature of the primary chamber shall be 800 ±50 °C.
4. The secondary chamber gas residence time shall be at least 1 (one) second at 1050 ±50 °C, with minimum 3% Oxygen in the stack gas.

B. Emission Standards

Parameters	Concentration mg/Nm^3 at (12% CO_2 correction)
1. Particulate matter	150
2. Nitrogen oxides	50
3. HCI	50

4. Minimum stack height shall be 30 metres above ground
5. Volatile organic compounds in ash shall not be more than 0.01%

Note

- Suitably designed pollution control devices should be installed /retrofitted with the incinerator to achieve the above emission limits, if necessary.
- Wastes to be incinerated shall not be chemically treated with any chlorinated disinfectants.
- Chlorinated plastics shall not be incinerated.
- Toxic metals in incineration ash shall be limited within the regulatory quantities as defined under the Hazardous Waste (Management and Handling Rules), 1989.
- Only low sulphur fuel like LDO/LSHS/ diesel shall be used as fuel in the incinerator.

STANDARDS FOR WASTE AUTOCLAVING

The autoclave should be dedicated for the purpose of disinfecting and treating bio-medical waste,

I. When operating a gravity flow autoclave, medical waste shall be subjected to:
   i. a temperature of not less than 121 °C and pressure of 15 pounds per square inch (psi) for an autoclave residence time of not less than 60 minute; or
   ii. a temperature of not less then 135 °C and a pressure of 31 psi for an autoclave residence time of not less than 45 minutes; or
   iii. A temperature of not less than 149 °C and pressure of 52 psi for an autoclave residence time of not less than 30 minute.

II. When operating a vaccum autoclave, medical waste shall be subjected to a minimum of one prevacuume pulse to purge the autoclave of all air. The waste shall be subjected to the following:

i. a temperature of not less than 121 °C and pressure of 15 psi per an autoclave residence time of not less than 45 minutes; or

ii. a temperature of not less than 135 °C and a pressure of 31 psi for an autoclave residence time of not less than 30 minutes.

III. Medical waste shall not be considered properly treated unless the time, temperature and pressure indicators indicate that the required time, temperature and pressure were reached during the autoclave process. If for any reasons, time temperature or pressure indicator indicates that the required temperature, pressure or residence time was not reached, the entire load of medical waste must be autoclaved again until the proper temperature, pressure and residence time were achieved.

IV. Recording of operational parameters

Each autoclave shall have graphic or computer recording devices, which will automatically, and continuously monitor and record dates, time of day, load identification number and operating parameters throughout the entire length of the autoclave cycle.

V. Validation test

Spore testing The autoclave should completely and consistently kill the approved biological indicator at the maximum design capacity of each autoclave unit. Biological indicator for autoclave shall be Bacillus stearothermophilus spores using vials or spore strips, with at least 1x 10^4 spores per milliliter. Under no circumstances will an autoclave have minimum operating parameters less than a residence time of 30 minutes, regardless of temperature and pressure, a temperature less than 121 °C or a pressure less than 15 psi.

VI. Routine Test

A chemical indicator strip/trap that changes colour when a certain temperature is reached can be used to verify and a specific temperature has been achieved. It may be necessary to use more than one strip over the waste package at different location to ensure that the inner content of the package has been adequately autoclaved.

STANDARDS FOR LIQUID WASTE

The effluent generated from the hospital should conform to the following limits:

Parameters	Permissible Limits
pH	6.5.-9.0
Suspended solids	100 mg/l
Oil and grease	10 mg/l
BOD	30 mg/l
COD	250 mg/l
Bio-assay test	90% survival of fish after 96 hours in 100% effluent.

These limits are applicable to those hospitals, which are either connected with sewers without terminal swage treatment plant or not connected to public sewers. For discharge into public sewers with terminal facilities, the general standards as notified under the Environment (Protection) Act, 1986 shall be applicable.

STANDARDS OF MICROWAVING

1. Microwave treatment shall not be used for cytotoxic, hazardous or radioactive wastes, contaminated animal carcasses, body parts and large metal items.
2. The microwave system shall comply with the efficacy test/routine tests and a performance guarantee may be provided by the supplier before operation of the unit.
3. The microwave should completely and consistently kill the bacteria and other pathogenic organisms that is ensured by approved biological indicator at the maximum design capacity of each microwave unit, biological indicators for microwave shall be Bacillus subtilis spores using vial or spore strips with at least 1×10^4 spores per milliliter.

STANDARDS FOR DEEP BURIAL

1. A pit or trench should be dug about 2 metres deep. It should be half filled with waste, then covered with lime within 50 cm of the surface, before filling the rest of the pit with soil.
2. It must be ensured that animals do not have any access to burial sites. Covers of galvanised iron/wire meshes may be used.
3. On each occasion, when wastes are added to the pit, a layer of 10 cm of soil shall be added to cover the wastes.
4. Burial must be performed under close and dedicated supervision.
5. The deep burial site should be relatively impermeable and no shallow well should be close to the site.
6. The pits should be distant from habitation, and sited so as to ensure that no contamination occurs of any surface water or erosion.
7. The location of the deep burial site will be authorised by the prescribed authority.
8. The institution shall maintain a record of all pits for deep burial.

Alternatively it is possible to adopt the emissions standards of USA or Europe for incinerators (see table 6.1 & 6.2).

Table 6.1: Emission guidelines for incinerators in USA

Pollutant	Small incinerator (≤91kg/hour)	Medium incinerator (>91-227kg/hour)	Large incinerator (>227kg/hour)
Particulate matter	115mg/m^3	69mg/ m^3	
Carbon monoxide (Co)	40 ppmv	40 ppmv	
Dioxins/furans	125ng/ m^3 total CCD/CDF or 2.3ng/ m^3 TEQ	125ng/ m^3 total CCD/CDF or 2.3ng/ m^3 TEQ	125ng/ m^3 total CCD/CDF or 2.3ng/ m^3 TEQ
Hydrogen chloride (HCl)	100 ppmv or 93% reduction	100 ppmv or 93% reduction	100 ppmv or 93% reduction
Sulfur dioxide (SO_2)	55 ppmv	55 ppmv	55 ppmv
Nitrogen oxides	250 ppmv	250 ppmv	250 ppmv
Lead	1.2mg/m^3 or 70% reduction	1.2mg/m^3 or 70% reduction	1.2mg/m^3 or 70% reduction
Cadmium	0.16mg/m^3 or 65% reduction	0.16mg/m^3 or 65% reduction	0.16mg/m^3 or 65% reduction
Mercury	0.55mg/m^3 or 85% reduction	0.55mg/m^3 or 85% reduction	0.55mg/m^3 or 85% reduction

Source: U.S. EPA, 1997

Table 6.2: Standards for incinerator in the European Union

Emission	Daily average (mg/m^3)	Hourly average (mg/m^3)	4-hour average (mg/m^3)
Total dust	5	10	-
Total organic carbon	5	10	-
Chlorine compounds	5	10	-
Fluorine compounds	1	2	-
Sulfur oxides as SO_2	25	50	-
Nitrogen oxides as NO_2	100	200	-
Carbon monoxide	50	100	-
Mercury	-	-	0.05
Cadmium and thallium	-	-	0.05
Lad, chromium, copper and manganese	-	-	0.5
Nickel and arsenic	-	-	0.5
Antimony, cobalt, vanadium, and tin	-	-	0.5
Dioxins and furans	-	-	0.1
Oxygen content		at least 6% at any moment	

Source: WHO, 1999

7.0 Treatment & Disposal of Waste in Local Condition.

In Village level health care centres & district level hospitals, it may not possible to install pyrolytic incinerator. In such area alternative low cost easy operation type of incinerator can be used. These are single chamber incinerator, brick or drum incinerator etc. As they are highly polluting system, there is a need of high level precaution before, during and after treatment of the waste.

For those places where autoclaves are also not available, there are some local methods, which are easily possible to operate. These are as follows

I. Pressure cooker (domestic type of pressure cooker or WHO/UNICEF modification) at 121^0 C for 30 minutes can be safely used.

II. At 100^0 C boiling for 20-30 minutes also sterilizes the instruments and equipments when autoclaving is not possible.

III. Below 100^0 C: Done by using a low temperature steam formaldehyde (LTSF) sterilizer, at a temperature of about 75^0 C at sub atmospheric pressures, and a vapour holding time of one hour.

Chemical disinfection is in primary phase in the country. This method is used for very basic & ordinary purpose. The main aim of this method is to make the health care premises and some reusable equipments hygienic.

Safe burial & municipal or ordinary landfill is practiced for the final disposal of health care waste in local areas.

8.0 Legislative & Regulatory Mechanism.

There is no clear and specific provision on medical waste management in Nepal. Medical wastes are also treated as other waste. Prevailing legal provisions on waste management are not sufficient for environmentally sound management of the medical waste. Mixing untreated infectious medical waste with other waste is a great risk to human health and environment. Not specifying responsible government agency for controlling and management of medical waste is also helping to deteriorate the situation of human health and environment. Making a separate Rule can only solve the problems that arise from the waste generated by the health care institutions.

8.1 International Agreements & principles

International agreement has been reached on a number of underlying principles that govern either public health or safe management of hazardous waste. These principles - outlined below-should be taken into consideration when national legislation or regulations governing healthcare waste management are formulated (Pruss et.al.1999):

- The Basel Convention, signed by more than 100 countries, concerns transboundary movements of hazardous waste; it is also applicable to health-care waste. Countries that signed the Convention accepted the principle that the only legitimate transboundary shipments of hazardous waste are exports from countries that lack the facilities or expertise to dispose safely of certain wastes to other countries that have both facilities and expertise. Exported waste should be labelled according to the UN recommended standards.
- The "polluter pays" principle implies that all producers of waste are legally and financially responsible for the safe and environmentally sound disposal of the waste they produce. This principle also attempts to assign liability to the party that causes damage.
- The "precautionary" principle is a key principle governing health and safety protection. When the magnitude of a particular risk is uncertain, it should be assumed that this risk is significant, and measures to protect health and safety should be designed accordingly.
- The "duty of care" principle stipulates that any person handling or managing hazardous substances or related equipment is ethically responsible for using the utmost care in that task.
- The "proximity" principle recommends that treatment and disposal of hazardous waste take place at the closest possible location to its source in order to minimize the risks involved in its transport. According to a similar principle, any community should recycle or dispose of the waste it produces, inside its own territorial limits.

8.2 Prospects for the Solution

For environmentally sound management of medical wastes, in the present legal context the best way to solve the problems is to frame a Rule, Medial Waste Management Rules, under the provision of Section 24 of the Environment Protection Act, 1997. This Section grants power to His Majesty's Government to frame a Rule on the matters of management and transportation of wastes, and on other necessary matters for the purpose of environment protection. The medical waste can also be managed framing a guideline under the provision of Section 23 of the Act. This Section of the Act grants power to His Majesty's Government to frame necessary guideline and makes compulsory to all concerned to abide by such guidelines. Making rules on medical waste management will be more effective, by its nature than making guidelines.

So, the Medical Waste Management Rules need to be framed and enforced covering the following matters.

1. Definition of Medical Waste.
2. Categorization of the medical waste.
3. Requirements for segregation, lebelling, packing of the medical waste.
4. Prohibition to mix with medical waste to non-hazardous waste.
5. Treatment provisions for biohazard and non-hazardous waste.
6. Provisions to require store for infectious medical waste prior to disposal.
7. Disposal provisions for treated medical waste.
8. Standards for Incinerator, and other technology for the proper management of Medical waste.
9. Prohibition to involve in medical waste management to non-trained personal.
10. Requirements for minimum safety measures for those personals who are involving on waste management.
11. Registration and licensing provisions for institutions or persons to involve in waste management.
12. Monitoring and evaluations.
13. Requirement to maintain treatment operation records.
14. Inspection provisions.
15. Access to justice, providing right to complain against: improper management; the impact of the waste on health and environment.
16. Access to information to all concern citizens.
17. Compensation provisions.
18. Provisions on penalties and compliance orders.
19. Specify authority to Ministry of Health for the enforcement of the Rules.

8.3 Regulatory Mechanism

The objective of regulative mechanism under the legal instrument is to establish a comprehensive control mechanism. These mechanisms are necessary to ensure that the technical and organizational methods prescribed are used in practice and that the improper dumping of waste is avoided.

To be effective the regulations as a minimum should establish a suitable regulating institutions at various levels and define the enforcement duties of the regulating authorities, which as minimum should include:

- Licensing of waste disposal facilities
- Licensing of waste transportation
- Routine and non-routine surveillance and monitoring of licensed operations, with powers of modification and revocation
- Collection and analysis of properly completed documentation and other data from major waste producers, storage depots, carriers of waste and waste treatment or disposal facilities

- Prosecution for illegal activities
- Preparation and implementation of waste management

Besides, the regulation should give effect to the waste management priorities both for the waste producers and waste managers. This as minimum depending upon the local situations shall include:

- Waste reduction
- Recycling and reuse
- Energy recovery
- Treatment to eliminate/reduce the potential to create environmental impacts/hazards
- Controlled landfill or other environmentally safe disposal.

The regulation should empower and encourage the national, district and local level regulating authorities to privities the waste management services and facilities and limit their role to regulating the waste management.
Cost recovery of the waste management is the other issue that needs adequate address in the regulation. The regulating authorities should be empowered to generate waste management cost by charging on the waste through direct and indirect means.

Annex I: Waste Management System in Bir Hospital

1. Introduction

Bir hospital is situated in the center of the city along the Kanti path and covers an area of around 50 ropani. This hospital has 394 beds and around 1200 staff. Bir hospital is becoming good referral center in all specialties and super-specialties.

This hospital also provides service to them who cannot afford high charges of the private hospitals and cannot go abroad for specialized treatment. As a result, Bir hospital is becoming a complex modern institution having number of independent departments with modern medical facilities.

2. Collection frequency of waste

Waste generated from most of the departments is collected three times a day. But some departments generating a little quantity of waste do not follow the schedule. The collection time of solid waste is presented in table 1.

TABLE 1:Collection Frequency of waste

S.No.	Collection frequency	Time Duration	Remarks
1	First Collection	5:00- 11:00	
2	Second Collection	14:00-17:00	
3	Third Collection	19:00-21:00	

The departments/units was visited thrice to collect the data and interact with the concerned official. Depending on the type of waste generated, the waste data has been obtained and presented either in quantity (no.), volume or weight basis.
Sorting is done to separate the different type of waste but in Bir hospital this step is not followed; and all the waste is collected and is mixed in municipality container. Waste is collected in 10 Liter and 15 Liter buckets. The collected waste at municipality container is disposed to the landfill site by the municipality on alternative days.

3. Quantification of waste

The waste produced from each department is measured and are presented as solid waste and liquid waste separately. Generally, the main forms of waste in Health Care centers are solid and liquid. Descriptive analysis of these types of waste is given below.

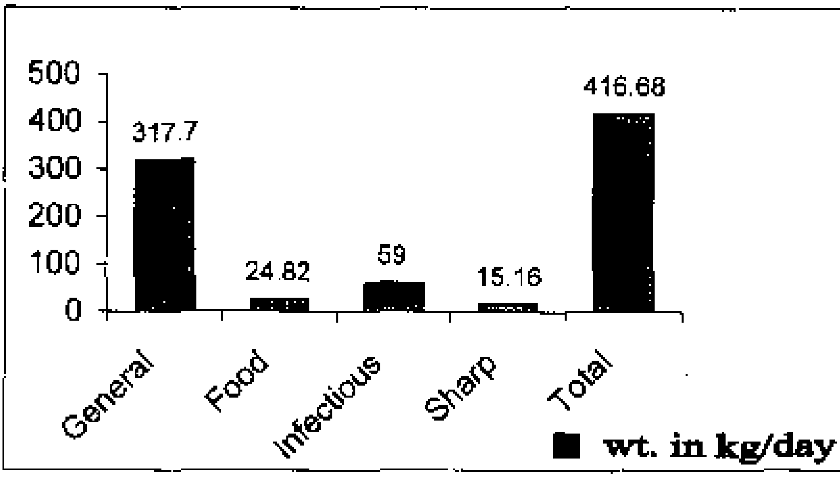
3.1 Solid Waste

Solid waste of infectious and on-infectious type produced from each department on weight basis is presented separately in following Table 2. (See fig. 1)

TABLE 2:Total Waste Generated in quantity (Kg/day)

S.No.	Ward	Non Infectious		Infectious	Sharp	Total
		General	Food			
A	Emergency	21.5	0.1	3.1	1.7	26.4
B	Medical Department					
	1.ICU/CCU	4.3	0.11	1.1	0.6	6.11
	2.Paying Medical ward	14.9	0.74	2.2	1.08	18.92
	3.Male Medical first floor	17.6	0.88	1.5	0.63	20.61
	4.Male Medical Second floor	17.8	0.6	2.3	0.81	21.81
	5.Female Medical	18.8	18.6	2.4	0.98	24.04
C	Surgical Departments					
	1.Orthopaedic	20.6	3.07	1.5	0.31	25.48
	2.Male Surgical	13.1	0.82	1.7	0.41	16.03
	3.Post Operative	12.6	0.69	4.3	1.22	18.81
	4.Female Surgical	19.1	2.35	3.1	0.51	25.06
	5.Acure Burn	14.4	0.38	9.3	0.4	24.48
	6.Burn Plastic	14.4	0.38	9.3	0.4	24.48
	7.Gastro-Urology	6.1	1.69	1.8	0.2	9.79
	8.NeuroSurgery Trauna Amex	8.7	1.65	1.5	0.18	12.03
	9.Cardiothoracic	12.7	0.6	0.3	0.15	13.75
	10.Neuro-Head	6.2	1.15	1.8	0.71	9.86
	11.E.N.T.	10.4	1.48	1.0	0.31	13.19
	12.General O.T.	12.6	0.15	1.9	0.59	15.24
	-13.Special O.T.	20.9	0.7	2.3	1.11	25.01
D	Cabin					
	1.Male Surgical	8.8	0.3	2.0	0.28	11.38
	2.E.N.T.	5.7	1.15	1.8	0.3	8.95
	3.New Cabin	6.5	0.35	2.3	0.22	9.37
E	Pathology	2.9	0	0.5	1.02	4.42
F	Blood Bank	0.6	0	0.2	0.32	1.12
G	Kitchen	3	2	0	0	5
H	Haemodialysis, CSSD.OPD Others	23.8	1.75	1.90	0.30	27.75
	Total	317.7	24.82	59.0	15.16	416.68

Figure1: showing the total waste generated in weight per day



The solid waste apart from the above mentioned is produced from Radiology department is as X-ray plate. The average number of X-ray plate used in a month is shown in table 3. Around 3% of X-ray plates are produced as waste.

TABLE 3: Monthly average number of x-ray used in x-ray and emergency department.

Department	size of x-ray plate used		
	8"x10"	10"x12"	12"x15"
Emergency	1400	2400	3500
X-ray Department	1100	800	2400
Total	2500	3200	5900
Grand Total	11600		
Waste produced monthly	75	96	72
Total	243		
Average Daily waste production	8		

The following table shows the percentage share by the waste by Volume and By Weight.

TABLE 4: Percentage share by different types of waste

S.No.	Type Of Waste	Waste by Volume		Waste by Weight	
		Ltr/day	% Share	Kg/day	% Share
1	General Waste	1289.8	73.48	317.7	76.24
2	Food Waste	62.62	3.56	24.82	5.96
3	Infectious	254.9	14.52	59.0	14.16
4	Sharp	147.94	8.44	15.16	3.64
	TOTAL	1755.26	100	416.68	100

3.2. Liquid waste

Liquid waste from each ward, department is generated as samples, cultures, blood, body fluid, faeces and urine from isolation rooms. Stool, vomit, cleaning, housekeeping and disinfectants, ethylene, chemicals generated from diagnostic procedure, chemotherapy

wastes, spent formaldehyde, waste pharmaceuticals, photographic processing chemicals, solvents, reagents, film developer etc, are discharged to municipal sewer.
Dentist generate amalgam waste (often known as silver filling) when they polish new fillings, drill or remove old fillings, extract teeth with amalgam fillings or left over after filling in the patients teeth . A suction device placed in the patient's mouth removes amalgam particle and discharges to municipal drain, which contains silver and mercury.

X-ray department uses Developer 4Kg in 45 Liter of water 5 times a week and contributes around 200 liter of waste per week.
Liquid waste of infectious type as samples, cultures, blood and body fluid, faeces and urine from isolation rooms, stool, vomit produced from each department on volume basis is presented in following table 5.

TABLE 5: Liquid Waste generated in Volume (Liter /day)

S. No.	Ward	Liquid waste
A	Emergency	6
B	Medical Department	
	1.ICU/CCU	0.7
	2.Paying Medical Ward	1.0
	3.Male Medical first floor	3.8
	4.Male Medical Second Floor	2560
	5.Femal Medical	1.25
C	Surgical Departments	
	1.Orthopaedic	0.2
	2.Male Surgical	0.7
	3.Post Operative	3.0
	4.Female Surgical	0.5
	5.Acute Burn	0
	6.Burn Plastic	0
	7.Gastro+Urology	0
	8.Neuro Surgery Trauma Amex	0.5
	9.Cardiothoracic	0
	10.Neuro+Head	0
	11.E.N.T.	2
	12.General O.T.	3
	13.Specisl O.T.	8
D	Cabin	
	1.Male Surgical	0.3
	2.E.N.T.	0.3
	3.New Cabin	0.95
E	Pathology	2.5
F	**Blood Bank**	0.15
G	**Kitchen**	-
H	**Haemodialysis, CSSD, OPD Others**	32040.15
I	**Radiology**	28.5
	Total	34663.5

4.0 Impact of health care waste

Health care waste includes a large component of general waste & a smaller portion of hazardous waste. The exposure to hazardous health-care waste can result in disease or injury. The hazardous nature of health care waste may be due to one or more of the following reasons:

- It contains infectious agent
- It is genotoxic.
- It contains toxic or hazardous chemicals.
- It is radio active.
- It contains sharps.

Hazard associated with hospital waste occurs at different stage of waste management as following.

- At point of waste generation
- During collection and segregation
- During storage
- During transportation.
- During treatment
- During disposal.

The waste produced at different service department of hospital comes in contact with health care workers. The health personnel are prone to the hazard associated with waste. Hazardous hospital waste when exposure, not only affects patients and hospital personnel, also to the human health and environment, which includes aesthetic factors and the risk of the pollution to air, water, and soil.

4.1 Impact of waste to the environment

Hospital waste contributes hazard to the environment as followings.

4.1.1 Contamination of Hospital Waste

General waste usually consists around 80% of total hospital waste and is non-hazardous. This type of waste do not requires special handlings. But if general waste were mixed with hazardous waste it would become as hazardous as others.

Food waste in general does not create any problem but food waste may create risk of infection if it comes in contact with communicable disease carried patients.

Bir hospital daily produces 317.7kg of general waste among total 416.68 kg. The percentage share by this type of waste is 76.24%. As it is composed of domesitc or household type of waste it represents minimal or no risks to human health and environment.

Bir hospital daily produces 24.82kg of food waste, which shares 5.96% by weight. In general food waste is treated as general waste unless the infections carrier patients contaminate it. At Bir hospital all the food waste is collected in the same container.

4.1.2 Contamination of Municipal Waste

Kathmandu metropolitan city takes responsibility of transferring the waste produced from Bir hospital. The waste collected in container is transferred to Teku Transfer Station (TTS). At present TTS receives around 200 m^3 of waste per day from Kathmandu city. The waste collected form health care institutions are transferred to TTS and the contribution of Bir hospital is around 1.8 m^3 of waste per day. Comparing with the total waste transferred to TTS, it is around 0.9%. Waste brought in TTS is sorted out manually by the scavengers and then transferred to the landfill site. In general retention time of waste in TTS is one day but at the time of emergency waste is stored for several weeks. The waste from Bir hospital makes all the other general waste infectious.

4.1.3 Contamination of river system

The liquid waste from Bir hospital contains a number of chemically hazardous waste generated as chemotherapy wastes, spent formaldehyde, photographic processing chemicals, disinfectants, amalgam waste, faeces, urine, blood, stool, vomit etc. and is drained to municipal sewer along with used domestic water. The amount of liquid waste is around 1,60,000 liters and is mixed in municipal sewer which have toxic effect on the natural ecosystem of receiving waters and receiving water pollutes ground water by percolating.

At Bir Hospital Formaldehyde is used around 25 liter a year, which represents a significant source of hazardous waste. For use in dialysis, formaldehyde is generally purchased as a 37 percent formaldehyde-in-water solution (Formalin). It is subsequently diluted with filtered, deionized water to achieve a final formaldehyde concentration of 2-4 percent. The formalin is either pumped or poured into dialysis machines to disinfect the membranes and the effluent is discharged to the sewer. In other departments, formaldehyde is generally used to preserve specimens with small quantities of waste generated and discharged to the sewer. Discharging a hazardous material to the sewer may be illegal and is generally undesirable management practice, even if sanitation authorities allow such disposal.

Bir hospital has a radiology department, where around 200 liter of liquid waste is produced in a week. Which consist photographic developing solutions used in X-ray departments and a fixer. The fixer normally contains 5-10 percent hydroquinone, 1-5 percent potassium hydroxide, and less than 1 percent silver. The developer contains approximately 45 percent glutaraldehyde. Acetic acid is a component of stop baths and fixer solutions. The waste is discharged to the sewer without treatment.

The source of mercury waste at hospitals is broken or obsolete equipment. Dental amalgam is another source of mercury. Only 30 patients attended Bir hospital for amalgam filling and mercury wastes are decreasing in quantity due to the substitution of electronic sensing instruments (thermometers, blood pressure gauges, etc.) for those containing mercury. Mercury losses due to spillage may not be frequently recovered; no mercury spill kits are present in hospitals. Mercury poisoning is primarily an occupational disease. Mercury vaporizes easily and diffuses through the lungs into the blood, then into the brain causing serious damage to the central nervous system. Mercury tends to concentrate in kidneys and prolonged exposure causes the kidney failure.

4.1.4 Soil pollution

Due to lack of separate landfill site waste is dumped haphazardly in low land and along the riverbank. The waste is collected at TTS and is stored to transfer to landfill site. Contaminated municipal waste may affect the quality of soil and watercourse when these waste are dumped.

4.1.5 Air pollution

At Bir hospital different types of Anesthesia was given for total 5527 cases. Nitrous oxide and the halogenated agents halothane (Fluothane), enflurane (Ethrane), isoflurane (Forane), and other substances are used as inhalation anesthetics. Exposure of health care personnel to these substances may result in acute toxic effects and possibly reproductive disorders and carcinogenesis. Nitrous oxide is supplied as a gas in cartridges or cylinders that are attached directly to the anesthetic administering equipment. Used containers are returned to the supplier. The halogenated anesthetic agents are supplied in liquid form, in glass bottles. Once empty, the bottles are handled as hazardous waste.

4.1.6 Aesthetic factors

The waste produced from the Bir hospital is disposed haphazardly at container provided by the municipality. Littering of the waste around the container and even in roadside has adverse effects.

Anatomical waste i.e. recognizable human body parts are not acceptable by the public to be disposed inappropriately.

4.2 Health Impact

4.2.1 Health impact to management staff

At preset there are 15 staffs deputed by KMC inside the transfer station as drivers, loaders, servicing personnel and guards. The crews responsible in transferring the waste into collection vehicle are at potential risks because hospital waste is mixed with other waste at transfer site.

4.2.2 Health impact to scavengers

Around 150 scavengers including family members living inside and around the TTS collect the scraps from the waste. They get affected from the biological and infectious wastes as they collect the waste without any protective measures or disinfections procedures. Several times the needle and syringes wound them. Table 7 summarized the people with risk.

Table 7: Number of People at risk

S. No.	Description		No. of persons
1.	Waste Generators	Health Care Workers	1200
2.	Persons involved in health	Patients	994
3.	Others	Visitors (678)/ Workers at disposal facilities (15)/Scavengers (150)/Others	906
		Total	3100

5.0 Treatment & Disposal of Waste

In the past there was an incinerator, which was later removed from Hospital premises due to some circumstances. Now there is separate autoclave for OT and there are other three

autoclaves for other departments. One of them is not functioning due to simple defect on a pipe. Remaining two autoclaves are running well for the sterilization of reusable medical instruments, which comes from different department of the Hospital. These reusable instruments are as follows:
-Vein section tray
-Bone Marrow tray
-Kidney Biopsy tray
-Cathrization tray
-Incision tray set
-Trochestomy set
-Sature Tray
-Lumber puncture
-Liver Biopsy tray
-Plural Biopsy C.S.S.D. form
-Aspiration tray.

All the other hazardous & non-hazardous waste are collected in the same bucket and disposed of without treatment in municipal waste container, which is situated in a car parking area adjacent to a busy road.
It is very easily seen that the waste management system of Bir Hospital is very poor. There is a need of extensive study for the safe & sustainable management of waste.

Annex II: Typical Maintenance Schedule for an Incinerator

Activity Frequency	Incinerator Component	Procedure
Hourly required	Ash removal conveyor	Inspect and Clean as
	Water quench pit	Inspect water level and fill as required
Daily the	Opacity monitor	Check operation of opacity monitor and check exhaust for visible emissions
	Oxygen monitor	Check operation of the oxygen monitor
	Thermocouples	Check operation of Thermocouples
	Underfire air ports	Inspect and clean as required
	Limit switches	Inspect for freedom of operation and potential obstructing debris
Weekly closeness of	Door seals	Inspect for wear, fit, and air leakage
	Ash pit/internal dropout sump	Clean after each shift on batch units that do not have continuous ash conveyor cleaning system.
	Heat recovery boiler tubes	Inspect and clean as required. (Clean weekly for 6 weeks to determine optimum cleaning schedule.)

	Blower intakes	Inspect for accumulation of lint, debris, clean as required
	Burner flame rods (gas-fired units)	Inspect and clean as required
	U.V scanner flame sensors	Inspect and clean as required
	Swing latches and hinges	Lubricate
	Hopper door support pins	Lubricate
	Ram feeder carriage wheels	Lubricate
	Heat recovery induced-draft fans	Inspect and clean fan housing as required. Check for corrosion and V-belt drives and chains for tension and wear.
Biweekly level	Hydraulic systems	Check hydraulic fluid and add the proper replacement fluid as required. Investigate sources of fluid leakage.
	Ash removal conveyor bearings	Lubricate
	Fuel trains and burners	Inspect and clean as required. Investigate sources of fuel leakage as required.
	Control panels	Inspect and clean as required. Keep panel security closed and free of dirt to prevent electrical malfunction.

Monthly	External surface of incinerator and stack	Inspect external "hot" surfaces. White spots or discoloration may indicate loss of refractory.
	Refractory	Inspect & repair minor wear areas with plastic refractory materials.
	Internal ram faces	Inspect for wear. These stainless steel faces may wear out and may require
Monthly (Contd.)		replacement in 1 to 5 years depending on service.
	Upper/secondary combustion chamber	Inspect and vacuum any particulate matter that has accumulated on the chamber floor
	Large combustion air blowers and heat recovery induced draft fans (those fans whose bearings are not sealed)	Lubricate
Semi-annually	Hydraulic cylinder clevis and trunnion attachments to all moving components	Lubricate
	Burner pilots	Inspect and adjust as required
	Hot external surfaces	Inspect and paint with high- temperature paint as required
	Ambient external surfaces	Inspect and paint with equipment enamel as required

Chains	Inspect and brush clean as required. Lubricate

Source: U. S. EPA 1989

Annex III: Types of Autoclaves

1. Benchtop Autoclave

Benching steam autoclaves are distinguished from other types of autoclaves because they are not connected to an external steam supply. These autoclaves generate their own steam from water at the beginning of each cycle. The manufacturers usually provide operators with information regarding the maintenance of the equipment with special attention to cleaning of the chamber and inspection of drain lines.

2. Standard Laboratory Autoclave

The standard laboratory autoclave is similar in size and operation to the benchtop autoclave, however, the laboratory autoclave usually has an external steam supply. Many of the maintenance concerns are the same as for the bench scale autoclave with the exception of steam generation and drainage system. Operational parameters and instrumentation are similar in most small systems and a similar maintenance schedule is suggested for these systems.

3. Prevacuum Autoclave

Prevacuum autoclave systems are large freestanding treatment units that are usually installed onsite at hospitals. They come in a variety of sizes to accommodate the needs of different sized facilities. All prevacuum autoclaves are equipped with an external vacuum supply and an external steam supply. Steam condensate is discharged directly to the sanitary sewer.

4. Large Gravity Displacement Autoclave

Large gravity displacement autoclaves are usually found in commercial waste treatment facilities because they can treat up to 3,000 pounds of waste per cycle. The steam is supplied by an external boiler. Most of the condensed exhaust steam is recirculated to the boiler for reuse. Other residual steam condensate that cannot be recirculated is discharged directly to the sanitary sewer.

Annex IV: Typical Maintenance Schedule for an Autoclave

Activity Frequency	Autoclave Component	Procedure
Every cycle signs of	Door seals	Inspect gaskets for wear, leakage and closeness of fit
Daily graphic	Temperature monitor	Check operation of temperature monitor and replace chart when necessary
Weekly obstructions or necessary	Steam lines	Inspect for leaks and repair if
	Sewer discharge lines	Inspect for obstructions or leaks Flush drains
Monthly	Autoclave chamber	Inspect. Clean and scrub if necessary
Annually	Temperature gauge	Calibrate with NIST reference thermometer
	Pressure gauge	Calibrate and inspect for readings consistent with the temperature recordings.

Source: U.S. EPA 1989

Annex V: List of some international vendors

Aegis Bio-Systems
409 W. Centennial Boulevard
Edmond, OK 73013
Ph. 888-993-1500 or 405-341-4667
Fax. 405-844-9364
www.jyd-1500.com
jrayburn@aegisco.com

Bio Arc
1140 66th Street N
Largo, FL 33773
Ph. 727-548-0640
Fax 727-549-8097

CerOx Corporation
760 San Aleso Avenue
Sunnyvale, CA 94086
Ph. 408-744-9180
www.cerox.com

Circle Medical Products, Inc.
3950 Culligan Avenue #D
Indianapolis, IN 46218
Ph. 317-541-8080

Sanitec International Holdings
26 Fairfield Place
West Caldwell, NJ 07006
Ph. 973-227-8855
Fax 973-227-9048
www.sanitec-inc.com
sales@sanitec.net

Tuttnauer Europe
P.O Box 7191
4800 GD Breda
The Netherlands
Ph. (31) 77-5423510
Fax (31) 76-5423540

KC MediWaste
4219 University Boulevard
Dallas, TX 75205
Ph. 214-528-8900
Fax 214-528-0467

Medical Disposal Devices
P.O Box 523
11 Halls Road
Old Lyme, CT 06371
Ph. 888-881-3477
Fax 860-434-3690
www.meddisposal.com
mdd@meddisposal.com

Pulse Pharma Pvt.
208,Ashirwad commercial complex
D-1, Green Park
New delhi-110016,India
Ph. 6868878

Byford Leasing Ltd.
CB-371 Naraina, Ring Road
New Delhi-110028, India
Ph. 91-11-5699250

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