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Impact assessment on solid health-care waste management in Addis Ababa, and identification of energy recovery possibility.

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Masters Degree in Environmental engineering.

By

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Acronyms

AIDS	Acquired immunodeficiency syndrome
ATSDR	Agency for Toxic Substances and Diseases Register
CRT	Cathode ray tube
ECSA	Ethiopian Central Statistics Agency
FMOH	Federal Ministry of Health
HBV	Hepatitis B virus
HCF	Health care facility
HCl	Hydrogen chloride
HCV	Hepatitis C virus
HCW	Health-care waste
HCWM	Health care waste management
HF	Hydrogen fluoride
HIV	Human immunodeficiency virus
PVC	Poly vinyl chloride
TB	Tuberculosis
WHO	World Health Organization

Abstract

In recent world the best way of protecting community health mainly depends on preventive methods rather than curative means. Due to this reason, having good solid health-care waste management and disposal in every health-care center is inevitable.

The present study is conducted in five systematically selected sample hospitals in Addis Ababa. The main objective of the study was to assess the impacts arose from the current health-care solid waste management, predict proper treatment and disposal mechanism and check the possibility of heat recovery during treatment of waste. The sampling method used is two-stage cluster sampling with 90 % confidence level. In these sample hospitals, solid waste was collected for one week from 84 randomly selected beds of the total occupied 505 beds. The mean waste generation rate for the city was estimated to be 1.227± 0.253 Kg/ day. bed, like wise the generation rate for the private and governmental hospitals were estimated applying the same data. To achieve these results different statistical estimation methods are used. On top of this, proper on site sorting was done in order to perform proximate analysis to seven waste categories. Based on this analysis the maximum infected hospital waste in the city was estimated to be 662 Kg/day. Additionally, an attempt is done to address the overall solid waste management trend all over the routes to disposal. Possible Environmental, health and social impacts are identified for every waste management route. Analyzing the data found, health, environmental and social impact has 37.7, 35.6, and 26.7% impact contribution respectively.

To identify the energy recovery of the treatment plant, secondary data from WHO that gives the minimum calorific value for infectious waste and estimated total generation rate of infectious waste in the city was used to determine the energy generation to be 104 Kg/hr, which is less than the capacity of medium sized steam generator. Since the capacity of the energy is less, possible ways of utilizing this small energy was suggested.

Finally, based on the results and findings of the present study, certain solid waste management, treatment and disposal recommendations are forwarded to improve the management and minimize the impact of solid health-care waste in Addis Ababa.

Chapter One - Introduction

1.1 Background

Environmental protection is becoming a burning issue having a great potential of attracting the attention of most of the society. Most of our environment consists of or covered with atmosphere (Air), hydrosphere (water), lithosphere (land) and biosphere. Nowadays in most metropolitan cities, the four conceptual spheres are becoming highly polluted. These spheres are directly or indirectly attacked or polluted by gradual increase of municipal waste generation. In most cities air, land and water are directly affected by solid waste accumulation. Considering all these facts the biosphere around the environment is attacked indirectly by loosing the permissible standard level for comfortable existence of different species living in other spheres.

Solid waste is defined as solid material arising from animal or human life activities and discarded permanently, or temporarily, as waste. It also includes deposited waste particulates temporarily suspended in air or water (Richard G. Bond & Conrad P. Straub, 1975). Depending on the generation point solid waste is classified in to municipal waste, agricultural waste, industrial waste, and energy generation wastes.

Municipal waste is categorized in to residential, institutional (private, office & public facilities), health-care (mainly Hospital), and construction and demolition wastes (FEPA, 2002). In most urban areas the overall contribution of health-care wastes is small compared to other types. Addis Ababa is a metropolitan city which has an estimated population of 2,973,000 with a growth rate in the past five years (which is from 2002 where the population was 2,570,000) is calculated to be 2.96 % (ECSA, 1999) the waste generation rate of Addis Ababa was estimated to be 0.11 Kg/person/day (Yetayal Beyene, 2005).

As well known Addis Ababa is not only the city for Ethiopia but also exercising the status of being the capital city of Africa. Even though being the city of Africa to be great it doesn't make the city perfect. The increase in being the economic, commercial, and industrial city of the country entails the fast population growth causing a burden in delivering proper, adequate and well-designed infrastructures as well as reliable, affordable and accessible social services for the city.

Like any other cities of developing countries, Addis Ababa exhibits high rate of population growth, low-income status, low level of education, poor personal hygiene and improper waste disposal practice (Worku Gebreselassie, 2003). Mainly in recent data's found from ECSA out of the top leading hospital morbidity cases some was caused by lack of sanitation facilities and awareness, mainly lack of toilet, enough water supply, un-proper sewerage system design, poor waste disposal site and waste management skill etc.

The main waste generated in the city is waste from households (76%), institutions (18%), and street sweepings (6%) (Taddesse Kuma, 2003). Referring the dry waste administration policy of Addis Ababa administration, out of the total dry waste created in the city 60-65 % was transported to a disposal area by the government, 5-10% of the waste is recycled, 5% was applied to the use of fertilizers and the remaining 25-30% is littered around fields, streets, rivers and assumed to pollute the environment (AACA, 2003). Irrespective of the waste type, the municipal dumping site was giving a service for all types of wastes including those wastes having a direct impact on the environment as well as the society. Of those wastes damped to the municipal site the hospital wastes are one of a kind.

According to the World Health Organization (WHO) the annual health care waste generation for the low-income countries was estimated to be 0.5-3.0 kg/ head of population (A. Pruss *et al.*, 1999). Assuming the smallest rating for the case of Addis Ababa, much amount of waste having enough percentage of hazard causing components is partially disposed to the environment with out any treatment to the open municipal dumping site (offsite disposal) and the rest of the portion is burned on open sites located at the waste generating health-care center (on site burning). These open sites are not regulated and controlled bearing great pollution.

The first hospital with 50 beds was established in Addis Ababa in1896 by the Russian Red Cross missionaries, since then only 29 hospitals were established where most of the increase in hospitals and health infrastructure was registered after the 1997 G.C.(Worku Gebreselassie, 2003) Based on the statistical data released by Ministry of Health on the year 2005-2006 the number of health-care institutions in the country were 138 hospitals, 635 health centres, 1,206 health stations, 5,955 health posts and 480 private clinics (FMOH, 2005/06). Out of the overall health-care centers 2.7 % in number and 28.2 % in bed capacity is located in Addis Ababa. The overall number of the health- care centres in Addis Ababa is shown in the table as follows:

Table 1.1 Number of health-care facilities in Addis Ababa

Type of health care centers	**Amount in Number**
Hospitals	34 including central hospitals
Health centres	29
Health stations	8
Health post	36
Total	105

Source: Federal Ministry of health of Ethiopia, 2005-2006 (Health and Health related indicators)

According to the Federal Ministry of Health data, released in the year 2001/02 the overall number of the health care centres in Ethiopia was 4,290 including hospitals, health centres, health stations, and health posts. Comparing this number with the data of the year 2005-2006 the variation shows 96.1% health-care center increment in the country, and in Addis even though the total data of the health-care centres shows decrease in number there was a slight increase of health-care centres that contribute high amount for the health-care waste generation, mainly hospitals, causing slight increase in bed number as shown in table-2.

Table 1.2 Comparison of health-care facilities in Addis Ababa between the year 2001/02 and 2005/06

Type of health care centres	**Distribution in number**			
	2001/2002		**2005/2006**	
		Bed no		**Bed no**
Hospitals, Including central hospitals	25	4,217	34	4,367
Health centres	24	122	29	174
Health stations	150	-	8	-
Health post	47	-	36	-
Private clinic not for profit	-	-	116	-
Total	246	4,339	223	4,541

Source: Federal Ministry of health of Ethiopia, 2005-2006 (Health and Health related indicators)

Problem statement

Health-care waste management in Addis Ababa is not well-organized and treated with special care; rather it is treated as one part of the municipal waste. In most developing countries including Ethiopia the risk behind solid health-care wastes is the management and disposing mechanism where in most cases health-care wastes are treated together with the municipal waste. The unscientific management and disposal of the health-care waste leads to the transmission of communicable diseases such as respiratory, skin, eye infections and several others including HIV, Hepatitis B, C, E and TB (Dr. Shamala.K et *al.*).

Even though the hazard behind these health-care wastes is well-known and different policies, guide lines were formulated (even though they are not enough) still much is expected on improving the sanitation basically improper health-care waste management and disposal. Irrespective of the risks due to this improper handling of health-care wastes in Addis Ababa, the actual situation was not studied well. Taking this in to account, performing this research on assessing the risks of health-care waste management and disposal in Addis Ababa will help the policy makers to focus on preparing a law that enforces the health centres to handle their waste properly, create awareness on the society and working personnel's around the health care centres and enforces the need towards having proper central disposal unit of the wastes.

In this research, solid health-care waste quantity, composition analysis, impact assessment and possibility of energy recovery from the waste for Addis Ababa is conducted applying sample hospitals, which are assumed to be the main generators of solid health-care waste. Sample health-care centers are chosen based on different criteria including capacity, specialization and ownership of the hospital.

Objective

The general objective of the thesis research will be:

Assessing the impacts caused by solid health-care waste management in Addis Ababa and recommend technically appropriate/ applicable central solid health-care waste disposal treatment plant. Moreover, possible way of using the heat energy release during the treatment will be identified.

The specific objectives of the thesis paper will be:

- Assessing the current solid waste management (collection, storage, transport, treatment and disposal of health care wastes)
- Solid waste classification of health care institutions around Addis Ababa
- Estimation of the solid waste amount coming out of the health care centers
- Determination of the capacity of the central health-care waste treatment plant for the city
- Identifying the way of energy recovery from the treatment plant

Chapter two - Literature review

2.1 General overview of health care waste

2.1.1 Definition of Health-care wastes

Most of the time the term health-care waste, hospital waste, medical waste, and infectious waste are used synonymously. The World Health organization defines health-care wastes as wastes including all the wastes generated by health-care establishments, health-care research facilities and laboratories, including health care wastes produced at home (A. Pruss *et al.*, 1999). Health-care waste includes all the wastes generated by medical activities. It embraces activities of diagnosis as well as preventive, curative and palliative treatments in the field of human and veterinary medicine. In other words, wastes are considered as health-care waste, when it is produced by a medical institution (public or private), a medical research facility or a laboratory. (UNEP/SBC& WHO, 2004)

According to the World Health Organization health-care wastes includes all the wastes, hazardous or not, generated during medical activities, and is also by-product of healthcare centers. Out of the total health-care waste generation between 75-90 % is non- risk or "general" health-care waste, comparable to domestic waste (A. Pruss *et al.*, 1999). The rest of the waste percentage is regarded as hazardous having high probability of causing health risks to the health-care centre workers and the community.

> The Basel Convention on the control of trans-boundary movement of hazardous wastes and their disposal, which was entered into force in, May 1992 mainly focus on the trans-boundary movement, handling and disposal of hazardous wastes. The parties to this convention take into consideration the risk of damage to human health and the environment caused by hazardous wastes. On this convention, even though the percentage of hazardous waste from health-care wastes is small, recognizing the adverse effect that these health-care wastes bear to the community and environment, it categorizes the waste under the hazardous waste category of No A4020, as clinical and related wastes.

2.1.2 Classification of Health-care wastes

The health-care waste is classified in two major categories mainly Non-hazardous and Hazardous or infectious.

Non-Hazardous health-care waste

General or non-hazardous wastes are those that are not contaminated with blood, body fluids, or other infectious agents or materials, such as latex gloves, papers, fabrics, glass, food residues, and containers (Khairun Nessa *et al.,* 2001). Another definition elaborates that Non-risk health-care waste includes all the waste that has not been infected like general office waste, packaging or left over food. They are similar to normal household or municipal waste and can be managed by the municipal waste services. They represent between 75% and 90% of the total amount of HCW generated by medical institutions. Three groups can be established as:

- **Recyclable waste**

It includes paper, cardboard, non-contaminated plastic or metal, cans or glass that can be recycled.

-Biodegradable HCW

This category of waste comprises for instance, left over food or garden waste that can be composted.

Other non-risk waste

This category include all the non-risk waste that do not belong to the above two categories (http://www.cdphe.state.co.us/hm/)

Hazardous health-care waste

Hazardous health-care wastes are discarded materials from health-care activities on humans or animals, which have the potential of transmitting infectious agents to humans. According to WHO hazardous health-care waste or "health-care risk waste" is further classified into Infectious waste, Pathological waste, sharps, pharmaceutical waste, genotoxic waste, chemical wastes, wastes with high content of heavy metals, pressurised containers and radio active wastes. These classifications for hazardous health-care wastes are discussed as follows:

Infectious wastes

Infectious waste is suspected to contain pathogens (bacteria, viruses, parasites, or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts (A. Pruss *et al.*, 1999). Certain factors are necessary for the spread of infectious diseases, and all must be present simultaneously for disease transmission to occur. These factors are presence of a pathogen, potent enough to cause infection (sufficient virulence); there has to be enough of the pathogen to have an effect (dose); there has to be a way to get into the body (portal of entry); and the person exposed must be vulnerable to infection (resistance of the host) (Lars M. Johannessen, 2000).

Pathological waste

Pathological waste consists of tissues, organs, body parts, human fetuses and animal carcasses, blood, and body fluids. This category should be considered as a subcategory of infectious waste, even though it may also include healthy body parts (A. Pruss *et al.,* 1999). These wastes are generated during surgery, autopsy or other medical procedures.

Sharps

Sharps are items that could cause cuts or puncture wounds, including needles, hypodermic needles, scalpel and other blades, knives, infusion sets, saws, broken glass, and nails. Whether or not they are infected, such items are usually considered as highly hazardous health-care wastes (A. Pruss *et al.,* 1999).

Pharmaceutical wastes

Pharmaceutical waste includes expired, unused, spilt, and contaminated pharmaceutical products, drugs, vaccines, and sera that are no longer required and need to be disposed of appropriately. The category also includes discarded items used in the handling of pharmaceuticals, such as bottles or boxes with residues, gloves, masks, and connecting tubing (A. Pruss *et al.,* 1999).

Genotoxic waste

Genotoxic waste is highly hazardous and may have mutagenic, teratogenic, or carcinogenic properties. It raises serious safety problems, both inside hospitals and after disposal, and should be given special attention. Genotoxic waste may include certain cytostatic drugs, vomit, urine, or faeces from patients treated with cytostatic drugs, chemicals, and radioactive material (A. Pruss *et al.,* 1999)**.**

Chemical waste

Chemical waste consists of discarded solid, liquid, and gaseous chemicals, for example from diagnostic and experimental work and from cleaning, housekeeping, and disinfecting procedures. Chemical waste from health-care may be hazardous or non-hazardous; in the context of protecting health, it is considered to be hazardous if it has at least one of the following properties:

- toxic;
- corrosive (e.g. acids of pH < 2 and bases of pH > 12);
- flammable;
- reactive (explosive, water-reactive, shock-sensitive);
- genotoxic (e.g. cytostatic drugs).

Non-hazardous chemical waste consists of chemicals with none of the above properties, such as sugars, amino acids, and certain organic and inorganic salts (A. Pruss *et al.*, 1999).

Wastes with high content of heavy metals

Wastes with a high heavy-metal content represent a subcategory of hazardous chemical waste, and are usually highly toxic. These types of wastes contain heavy metals like Mercury, Cadmium, and Lead (A. Pruss *et al.*, 1999). The main sources of mercury are spillages from broken clinical equipment, such as thermometers, blood pressure gauges, etc. Cadmium sources in the health-care centers are discarded batteries. And the application of lead reinforcement in wooden panels for the radiation proofing is the major source of lead (Khairun Nessa *et al.*, 2001).

Radioactive wastes

These include solid, liquid and pathological wastes that are contaminated with radioactive isotopes of any kind (Khairun Nessa *et al.*, 2001).

Pressurized containers

Various types of gas are used in health-care and are often stored in pressurized cylinders, cartridges, and aerosol cans. Many of these, once empty or of no further use (although they may still contain residues) are reusable, but certain (types notably aerosol cans) must be disposed of.

2.2 Sources and Generation of health-care wastes

2.2.1 Sources of health-care wastes

According to “the world bank” the two main causes of health-care waste generation in developing countries are emergency relief donations (leftover from international donor response to either a humanitarian crisis or a natural disaster) and long-term healthcare services (DHM, 2000)**.**

Health-care wastes are generated from different sources (Khairun Nessa *et al.*, 2001). Depending on these sources the waste type varies accordingly in amount. These sources are classified as:

I. Major sources:

a) Hospitals, e.g. university hospital, general hospital, district hospital,
b) Other healthcare establishments, e.g. emergency medical care services, dispensaries, obstetric and maternity clinics, outpatient clinics, dialysis centers, first-aid posts and sick bays, long-term health-care establishments and hospices, transfusion centers, military medical services
c) Related laboratories and research centers, e.g. medical and biomedical laboratories, biotechnology laboratories and institutions, medical research centers,
d) mortuary and autopsy centers,
e) animal research and testing facilities,
f) blood banks and blood-collection services; and
g) nursing homes for the elderly. (Khairun Nessa *et al.*, 2001)

II. Minor sources:

a) small healthcare establishments, e.g. physician’s office, dental clinics, and acupuncturists,
b) specialized healthcare establishments and institutions with low waste generation, e.g. psychiatric hospitals, institutions for disabled persons,
c) non-health activities involving intravenous or subcutaneous interventions, e.g. cosmetic piercing and tattoo parlours,

d) funeral services,
e) ambulance services; and
f) home treatment. (Khairun Nessa *et al.*, 2001)

iii. Support service sources:

Out of the many supporting sections pharmacy, laundry, kitchen, engineering, administration, and patient's attendance units have solid health-care contribution (Khairun Nessa *et al.*, 2001).

2.2.2 Composition and generation rate of health-care wastes

The generation rate of healthcare waste varies not only from country to country or on national income but also on different factors like waste-management methods, type of health-care establishments, hospital specializations, proportion of reusable items employed in health-care, and proportion of patients treated on a daily basis (A. Pruss *et al.,* 1999) and (Khairun Nessa *et al.*, 2001). The variation in amount of generating wastes according to the type of health-care establishments was different accordingly. According to WHO the average daily waste generation of different health-care centers is shown below in table 2.1.

Table 2.1 Health-care waste generations according to source size

Source	**Daily waste generation (kg/bed**)
University hospital	4.1-8.7
General hospital	1-4.2
District hospital	0.5-1.8
Primary healthcare centre	0.05-0.2

Source (A. Pruss *et al.,* 1999)

In most countries different surveys have been done to predict the rate and composition of health-care wastes, as a result the total generation of health-care wastes in North America is found to be 7-10 kg/bed. day, Latin America is 3 kg/bed. day, Western Europe is 3-6 kg/bed. day, Eastern Europe is 1.4-2 kg/bed. day, Middle East is 1.3-3 kg/bed. day, East Asia (high-income countries) is 2.5-4 kg/bed. day, and East Asia (middle-income countries) is 1.8-2.2 kg/bed. day (Khairun Nessa *et al.*, 2001).

According to WHO estimation used for preliminary planning health-care wastes composition is discussed in table 2-2 as shown below:

Table 2-2 Health-care waste compositions for preliminary estimation

Health-care Waste type	Health-care waste amount in percent
General health-care waste, which may be dealt with by the normal domestic and urban waste management system;	80%
Pathological and infectious waste;	15%
Sharps waste	1%
Chemical or pharmaceutical waste	3%
Special waste, such as radioactive or cytostatic waste, pressurized containers, or broken thermometers and used batteries.	< 1%

Source (A. Pruss *et al.,* 1999)

Even though this estimation has been given by WHO it is recommended by different experts, as well as WHO, performing detailed study before any further planning was necessary.

2.3 Health-care waste management

Nowadays, one of the main concerns regarding health-care waste generation is finding ways of reducing or totally controlling the negative impacts that it bear to the environment, social and economic welfare of the country. Recently the basic solution developed to be the best option for controlling those negative impacts is practicing the best health-care waste management in the country level.

Health-care waste management is a properly designed route of health-care waste generated in the health-care facility from their point/source of generation to their final disposal. This stream is composed of several steps that include: generation, segregation, collection, on-site transportation, on-site storage, offsite transportation (optional), treatment and disposal of the HCW (UNEP/SBC& WHO, 2004). The earliest step in any solid waste management scheme is that finding the way of minimizing the generation of waste. In this portion the seven basic units of health-care waste management are discussed in detail as follows.

HC Waste minimization

Waste minimization practice is the best practice in reducing waste generation in any solid waste management system. Before producing waste, it should be investigated whether the amount of waste generated could be minimized in order to reduce efforts in subsequent handling, treatment and disposal operations (UNEP/SBC& WHO, 2004)

HC waste minimization scheme can be practiced by applying reformed purchasing policy, stock management, and recycling of certain types of wastes. Even though the recycling or reusing is one method of waste minimization, it has almost disappeared due to the marketing of single use items and the need to prevent the spread of nosocomial diseases. Mainly this is particularly the case for medical items such as syringe needles. There are, however, other opportunities for recycling or reuse, in particular for objects / items which are not directly used for health-care treatment (paper, cardboard, glass, metal containers, plastic wrappings…). One of the most efficient measures for waste reduction lies in the careful management of medical stocks in the hospital pharmacies (UNEP/SBC& WHO, 2004).

Significant reduction of the waste generated in health-care establishments and research facilities may be encouraged by the implementation of certain policies and practices, including the following:

• **Source reduction**: measures such as purchasing restrictions to ensure the selection of methods or supplies that are less wasteful or generate less hazardous waste, careful management of stores will prevent the accumulation of large quantities of outdated chemicals or pharmaceuticals and limit the waste to the packaging (boxes, bottles, etc.) plus residues of the products remaining in the containers. These small amounts of chemical or pharmaceutical waste can be disposed of easily and relatively cheaply, whereas disposing of larger amounts requires costly and specialized treatment, which underlines the importance of waste minimization.

Reducing the toxicity of waste is also beneficial, by reducing the problems associated with its treatment or disposal. For example, the Supply Officer could investigate the possibilities of purchasing PVC-free plastics that may be recycled or of goods supplied without unnecessary packaging.

- Management and control measures at hospital level include:
    - Centralized purchasing of hazardous chemicals.
    - Monitoring of chemical flows within the health facility from receipt as raw materials to disposal as hazardous wastes.

- Stock management of chemical and pharmaceutical products embrace:
    - Frequent ordering of relatively small quantities rather than large amounts at one time (applicable in particular to unstable products).
    - Use of the oldest batch of a product first.
    - Checking of the expiry date of all products at the time of delivery (A. Pruss *et al.,* 1999).

Recyclable products: use of materials that are safely recycled, either on-site or off-site can save some resource for the health-care facilities. Medical and other equipment used in a health-care establishment may be reused provided that it is designed for the purpose and will withstand the sterilization process. Reusable items may include certain sharps, such as scalpels and hypodermic needles, syringes, glass bottles and containers, etc. After use, these should be collected separately from non-reusable items, carefully washed (particularly in the case of hypodermic needles, in which infectious droplets could be trapped), and may then be sterilized. Although reuse of hypodermic needles is not recommended, it may be necessary in establishments that cannot afford disposable syringes and needles. Plastic syringes and catheters should not be thermally or chemically sterilized; they should be discarded (A. Pruss *et al.,* 1999).

HC Waste segregation

The first basic part of health-care waste management is waste segregation. It is one of the most important steps to successfully manage HCW. Given the fact that only about 10-25% of the HCW is hazardous, treatment and disposal costs could be greatly reduced if a proper segregation were performed. Segregating hazardous waste from non-hazardous waste reduces also greatly the risks of infecting workers handling HCW. Actually, the part of the HCW that is hazardous and requires special treatment could be reduced to some 2-5% if the hazardous part were immediately separated from the other waste (UNEP/SBC& WHO, 2004).

Segregation should always be the responsibility of the waste producer, should take place as close as possible to where the waste is generated, and should be maintained in storage areas and during transport. The same system of segregation should be in force throughout the country. The most appropriate way of identifying the categories of health-care waste is by sorting the waste into colour-coded plastic bags or containers (A. Pruss *et al.,* 1999) **.**

According to WHO the colour coding recommended is three colour coding format as described below according to the waste that can be handled.

1. Yellow marked "HIGLY INFECTIOUS" colour of container for highly infectious waste;
2. Yellow container for other infectious wastes like anatomical and Pathological wastes;
3. Yellow marked "SHARPS" for container sharps;
4. Brown coloured containers for chemical and pharmaceutical wastes, and
5. Black for general wastes. (A. Pruss *et al.,* 1999)

In addition to the colour coding mechanism suggested the container type should be well designed to fit the criteria's mentioned below for the needed purpose.
The container for highly infectious waste should be strong, leak-proof plastic bag, or container capable of being autoclaved. Highly infectious waste should, whenever possible, be sterilized immediately by autoclaving. These bags and containers for infectious waste should be marked with the international infectious substance symbol See (figure2.1). In the case of other infectious wastes it should be leak proof plastic bag or container. To handle sharps the container should be rigid and impermeable so that they safely retain not only the sharps but also any residual liquids from syringes. To discourage abuse, containers should be tamper-proof (difficult to open or break) and needles and syringes should be rendered unusable. Where plastic or metal containers are unavailable or too costly, containers made of dense cardboard are recommended (WHO, 1997); these fold for ease of transport and may be supplied with a plastic lining See (figure 2.2). For chemical, pharmaceutical and general wastes the container can be plastic bag or container

with the specified colour. There is no colour marking for radioactive waste container but as a specification it should be Lead box, labelled with the radioactive symbol. See (figure 2.3). The lead box will protect the emission of radioactive materials.

Table 2.3 Recommended colour-coding for health-care waste

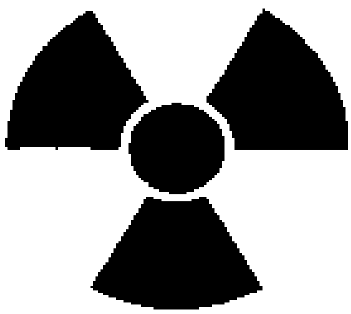
Type of waste	Colour of container and markings	Type of container
Highly infectious waste	Yellow marked "HIGHLY INFECTIOUS"	Strong, leak-proof plastic bag, or container capable of being autoclaved
Other infectious waste, ➢ Pathological and ➢ Anatomical wastes	Yellow	Leak proof plastic bag or container
Sharps	Yellow marked "Sharps"'	Puncture-proof container
Chemical and pharmaceutical wastes	Brown	Plastic bag container
Radioactive wastes	-	Lead box, labelled with the radioactive symbol
General health-care waste	Black	Plastic bag

Source (A. Pruss *et al.,* 1999)

Figure 2.1 International infectious substance symbol

Figure 2.2 Collapsible cardboard sharp container

Figure 2.3 International symbol for radio activity



Source (A. Pruss *et al.,* 1999)

Collection, On-site Storage and transportation of waste

Collection of HCW

The next basic steps in HCWM are proper collection, transportation and storage in the health-care facility (HCF). In order to avoid accumulation of the waste, it must be collected on a regular basis and transported to a central storage area within the HCF before being treated or removed. The collection must follow specific routes through the HCF to reduce the passage of loaded carts through wards and other clean areas. Considering the handling of HCW great care should be taken by the hospital staff to protect occupational hazard. The most important risks are linked with the injuries that sharps can produce. When handling HCW, sanitary staff and cleaners should always wear protective clothing including, as minimum, overalls or industrial aprons, boots and heavy duty gloves (UNEP/SBC& WHO, 2004).

The ancillary workers in charge of waste collection should follow certain recommendations:

- Waste should be collected daily (or as frequently as required) and transported to the designated central storage site.
- No bags should be removed unless they are labeled with their point of production (hospital and ward or department) and contents.
- The bags or containers should be replaced immediately with new ones of the same type (A. Pruss *et al.,* 1999).

On-site storage

After collection of HCW is performed on each ward, different sections and kitchens of the health-care facility (HCF) there should be well designed temporary storage place in the compound, having the size according to the volume of waste generated as well as the frequency of collection. The centrally located storage room should also be secured. In-house storage may consist of two levels: a) A well-ventilated room at or near the ward, where waste collectors will pick up the waste; and b) A centrally located storage room, where temperatures can be kept low (e.g. air-conditioned), easily cleanable until waste is picked up for treatment (DHM 2000).

The facility should not be situated near to food stores or food preparation areas and its access should always be limited to authorised personnel (UNEP/SBC& WHO, 2004).

Unless a refrigerated storage room is available, storage times for healthcare waste (i.e. the delay between production and treatment) should not exceed the following:

- temperate climate: 72 hours in winter
  48 hours in summer
- warm climate: 48 hours during the cool season
  24 hours during the hot season

Cytotoxic *waste* should be stored separately from other health-care wastes in a designated secure location (A. Pruss *et al.,* 1999).

On-site transportation

Health-care waste should be transported within the hospital or other facility by means of wheeled trolleys, containers, or carts that are not used for any other purpose (A. Pruss *et al.,* 1999).

The carts should be 1) easy to load and unload, 2) have no sharp edges that could damage waste bags or containers and 3) easy to clean. The vehicles should be cleaned and disinfected daily with an appropriate disinfectant (A. Pruss *et al.,* 1999).

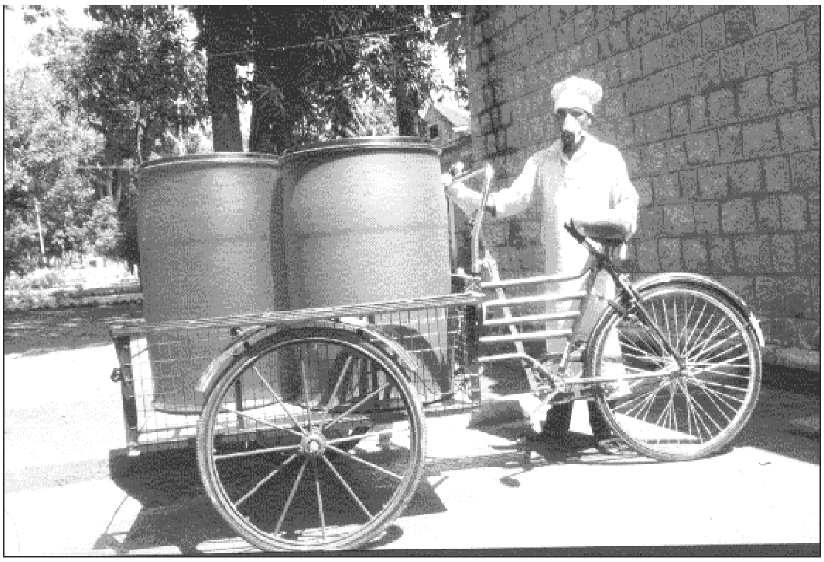


Figure 2.4 Sample on-site waste transportation cart

Off-site transportation of waste

Off-site transportation is required when hazardous HCW is treated outside the HCF. The waste producer is then responsible for the proper packaging and labelling of the containers that are transported. One of the reasons for labelling HCW bags or containers is that in case of an accident, the content can be quickly identified and appropriate measures taken. The transportation should always be properly documented and all vehicles should carry a consignment note from the point of collection to the treatment facility. Furthermore, the vehicles used for the collection of hazardous / infectious HCW should not be used for any other purpose (UNEP/SBC& WHO, 2004).

As mentioned earlier, during transportation there should be labelling system and this labelling should comply with the United Nations Recommendations and contain at least:

- The United Nations substance class (e.g. class 6, division 6.2, UN no 3291 for infectious waste); (See annex 1)
- The proper shipping name and the total quantity of waste covered by the description (by mass or volume);
- The date of collection (UNEP/SBC& WHO, 2004).

Transportation vehicles: Before transporting the waste out of the health-care centre necessary procedures should be fulfilled between the consignor, carrier, and consignee.

According to the WHO the health-care transportation vehicles should fulfil the following specification for safety of the community from solid health-care waste hazard. These specifications are:

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

- The internal finish of the vehicle should allow it to be steam-cleaned, and the internal angles should be rounded.
- The vehicle should be marked with the name and address of the waste carrier.
- The international hazard sign should be displayed on the vehicle or container, as well as an emergency telephone number.

Vehicles or containers used for the transportation of health-care waste should not be used for the transportation of any other material. They should be kept locked at all times, except when loading and unloading (A. Pruss *et al.,* 1999).

Treatment and Disposal

Solid waste treatment and proper disposal are the final options in the health-care waste management. Treatment mechanisms are classified in to two groups according to the place of action, these are:

- On- site treatment
- Off-site treatment

On- site treatment: This option is often the only one possible in the rural HCFs of the primary sector but on-site treatment can be also carried out for HCW generated in major HCFs. On-site treatment facilities are particularly appropriate in areas where hospitals are situated far from each other and the road system is poor.
The advantages of providing each health-care establishment with an on-site treatment facility includes convenience and minimization of risks to public health and the environment by confinement of hazardous / infectious HCW to the health-care premises. However, the treatment costs may be high if there are many hospitals: extra technical staff may be required to operate and maintain the facilities and it may be difficult for the relevant authorities to monitor the performance of many small facilities. This may result in poor compliance with operating standards, depending on the type of facilities, and increased environmental pollution (UNEP/SBC& WHO, 2004)

Off-site treatment: The HCW generated in a HCF can be treated off-site, when centralized regional facilities exist. Although off-site treatment increases dependency of the HCF on an external actor and requires a fine tuned transportation system, it provides the following advantages:

- Hospitals will not have to devote time and personnel to manage their own installations;
- Efficient operation can be more easily ensured in one centralized facility than in several plants where skilled workers may not be readily available;
- Greater cost-effectiveness for larger units, through economies of scale;
- Future modifications or expansions (relating to flue-gas cleaning systems of incinerators, for example) are likely to be less expensive;
- Where privatization of facilities is seen as a desirable option, this can be achieved more easily on a regional basis than for numerous small units;
- It will be easier for the relevant government agencies to supervise and monitor the facilities;
- Air pollution may be more easily kept to a minimum at a centralized plant (costs of monitoring and surveillance as well as flue-gas cleaning, for example, will be reduced) (UNEP/SBC& WHO, 2004).

2.4 Impact of poor health-care waste management

Health-care wastes has small amount of hazardous waste having high potential of causing negative impacts to the health, environment and society. The exposure to these hazardous wastes could lead to the diseases or injury. Illness of the exposed person would cost socially and economically. Improper management and disposal of health-care wastes causes a direct or indirect negative impact on the four spheres of the environment.

The capability of the HCW to cause hazard arise from having the following characteristics:

- it contains infectious agents;
- it is genotoxic;
- it contains toxic or hazardous chemicals or pharmaceuticals;
- it is radioactive;
- it contains sharps (A. Pruss *et al.,* 1999).

Negative impact of health-care wastes can be categorized into two as impacts arising from the occupational exposure and impacts caused from non-occupational exposure. According to the World Health Organization the persons at risk are individuals exposed to hazardous health-care waste, including those within health-care establishments that generate hazardous waste, and those outside these sources who either handle such waste or are exposed to it as a consequence of careless management. The main groups at risk are the following:

- Medical doctors, nurses, health-care auxiliaries, and hospital maintenance personnel;
- Patients in health-care establishments or receiving home care;
- Visitors to health-care establishments;
- Workers in support services allied to health-care establishments, such as laundries, waste handling, and transportation;

Workers in waste disposal facilities (such as landfills or incinerators), including scavengers (A. Pruss *et al.,* 1999).

2.4.1 Health impacts of health care waste

As mentioned earlier the medical and supporting staff as well as the sanitary laborers can be injured if the waste has not been managed safely. According to their source of causes health impacts are categorized as:

- Impact of infectious wastes and sharps
- Impact of chemical and pharmaceutical wastes
- Impact of genotoxic wastes.
- Impact of radioactive wastes

Impacts from infectious wastes: Infectious wastes are hazardous because it has pathogens. Pathogens in infectious waste may enter the human body by a number of routes:

- through a puncture, abrasion, or cut in the skin;
- through the mucous membranes;
- by inhalation;
- by ingestion (A. Pruss *et al.,* 1999).

Since there is a great evidence for transmission of HIV, HBV and HCV through the puncture and injuries from used syringes contaminated by human blood, a great emphasis is given to them. Cultures of pathogens and contaminated sharps, particularly hypodermic needles, are the waste items that represent the most acute potential hazards to health. Sharps not only cause cuts or punctures but may also infect these wounds if they are contaminated with pathogens. Because of this, double risk of injury and transmission of disease exists, due to this reason sharps are considered to be the main causes of infection.

The principal concern is that infections may be transmitted by subcutaneous introduction of the causative agents, e.g. viral blood infections. Hypodermic needles constitute an important part of the sharps waste category and are particularly hazardous, because they are often contaminated with patient's blood (Khairun Nessa *et al.*, 2001).

The existence of bacteria in health-care establishments, resistant to antibiotics and chemical disinfectants also contribute to the hazards created by poorly managed health-care waste. This hazard is categorized under the impact from infectious wastes due to inhalation or ingestion (Khairun Nessa *et al.*, 2001).

For serious virus infections such as HIV/AIDS and hepatitis B and C, health-care workers-particularly nurses-are at greatest risk of infection through injuries from contaminated sharps (largely hypodermic needles). Other hospital workers and waste-management operators outside health-care establishments are also at significant risk, as are individuals who scavenge on waste disposal sites (although these risks are not well documented). The risk of this type of infection among patients and the public is much lower. According to the World Health Organization it is difficult to assess the overall cases of health care impacts caused specially in developing countries.

According to the estimation made by US Agency for Toxic Substances and Diseases Register (ATSDR), in their report to Congress on medical waste, the annual number of HBV infections in the USA resulting from exposure to health-care waste is between 162 and 321, out of an overall yearly total of 300,000 cases. In France for the year 1992, eight cases of HIV infection were recognized as occupational infections. Two of these cases, involving transmission through wounds, occurred in waste handlers. Out of the 39 occupational infection HIV cases, registered by Centers for Disease Control and Prevention in USA (in 1994) different cases are registered as 32 from hypodermic needle injuries, 1 from blade injury, 1 from glass injury (broken glass from a tube containing infected blood), 1 from contact with non-sharp infectious item, 4 from exposure of skin or mucous membranes to infected blood. And this number rises to 51 cumulative recognized effects by June 1996. All cases were nurses, medical doctors, or laboratory assistants (A. Pruss *et al.,* 1999).

The above proportion shows much of the infection caused are due to improper handling of needles, and these has a major effect on the health care workers. This shows the impact on the general public out of infectious waste and sharps to be low in comparison. The estimated risk of infection with HIV or viral hepatitis after hypodermic needle puncture based on data from the world is summarized as in table bellow, and according to the data the potential for HBV-associated infection following contact with medical wastes is likely to be higher than that associated with HIV (A. Pruss *et al.,* 1999).

Table: 2.4 Risk of infection after hypodermic needle puncture

Infection type	Risk of infection in percent
HIV	0.3
Viral hepatitis B	3
Viral hepatitis C*	3-5

* Data from Japan

Source (A. Pruss *et al.,* 1999).

Since there is less awareness, poor training of exposed personnel and the community, less resource of waste management and poor supervision and the like, extrapolation of these data to developing countries would be less rigorous, with the result that more people are likely to be exposed to health-care wastes, both within and outside health-care establishments.

The WHO estimates that over 20 million infections of hepatitis B, C and HIV occur yearly due to unsafe injection practices (reuse of syringes and needles in the absence of sterilization) (UNEP/SBC& WHO, 2004).

Impact of chemical and pharmaceutical wastes: There is no scientifically documented data that shows the impact of chemical and pharmaceutical wastes causing a problem on the public health as of the industrial waste, many examples may be found of extensive intoxication caused by industrial chemical waste (A. Pruss *et al.,* 1999). But many cases of injury or intoxication resulting from the improper handling of chemicals and pharmaceuticals in healthcare establishments have been found.

Pharmacists, anesthetists, nursing, and maintenance personnel may be at risk of respiratory and dermal diseases caused by exposure to such substances, such as vapor, aerosols, and liquids. To minimize this type of occupational risk, less-hazardous chemicals should be substituted whenever possible. Those personnel's who are likely to be exposed should use protective equipment. Premises where hazardous chemicals are used should be properly ventilated, and personnel at risk should be trained in preventive measures and in emergency care in case of accident (Khairun Nessa *et al.*, 2001).

Impacts of genotoxic waste: Due to the difficulty of assessing the human exposure, there is few data on the long-term health impacts of genotoxic health-care waste. Numerous published studies have investigated the potential health hazard associated with the handling of antineoplastic drugs, manifested by increased urinary levels of mutagenic compounds in exposed workers and an increased risk of abortion. A recent study has demonstrated that exposure of personnel cleaning hospital urinals exceeded that of nurses and pharmacists, these individuals were less aware of the danger and took fewer precautions (A. Pruss *et al.,* 1999).

Impacts of radioactive wastes: Several accidents resulting from improper disposal of nuclear therapeutic materials have been reported, with a large number of persons suffering from the results of exposure. According to WHO, due to the poor trend of reporting health-care waste impact there was only one case of carcinogenic impact on the general population that took place in Brazil, linked to exposure to radioactive hospital waste has been analysed and fully documented. And this exposure causes 249 peoples either died or suffered severe health problem.

In many reports the only recorded accidents involving exposure to ionising radiations in health-care settings have resulted from unsafe operation of X-ray apparatus, improper handling of radiotherapy solutions, or inadequate control of radiotherapy. There is lack of awareness or negligence on reporting the cases caused by disposal of radioactive waste exposure.

2.4.2 Environmental impacts of health-care waste

Considering the environmental impact of the health-care wastes enough concern was not given to it. Even though health-care waste has a direct impact on the environment, enough work was not done in developing countries. Apart from the risk to the patients and health-care personnel, consideration must be given to the impact of health-care waste to the general public and the environment. In particular, attention should be paid to the possible pollution of the air, water and soil including the aesthetic aspects (DHM, 2000).

On the generation site if the waste is not segregated, stored and handled properly the spill from containers, vent from storage rooms, smell coming from the health-care waste does have direct impact on the health-care centre's environment. Controlling mechanisms of these spills, smell, and vent of different toxic chemicals from the waste are not well developed, especially in developing countries. These mechanisms include well-designed management skill, developing awareness of the workers in the premises, developing well storage and distribution mechanisms of different stores in the health care centre.

In the route from collection to disposal, if the proper health-care waste management is not practiced the generation of vents from storage areas cause threat to the atmospheric pollution around the health-care vicinity. The drop downs from the transportation mechanisms contaminates the soil and the spill of radioactive material from radioactive wastes causes high impact on the environment.

From the disposal point of view the dumping of HCW in uncontrolled areas can have a direct environmental effect by contaminating soils, surface waters and underground waters.

During health-care waste treatment like incineration, if no proper filtering is done, air can also be polluted causing illnesses to the nearby populations. Particularly for those wastes containing chlorine or heavy metals, under certain conditions (such as insufficiently high incineration temperatures, inadequate control of emissions) release toxic material like dioxins, carbon dioxide, nitrogen oxides, and certain toxic substances (e.g. metals, halogenic acids), and particulate matter, plus solid residues in the form of ashes that causes carcinogenic, irritant, mutagenic effect on the society. The leachate from ashes of incinerated health-care wastes, sludge from wastewater treatment and from cooling of ash, in case of chemical disinfections leakage or after disposal, it may create serious contamination of soil, which is the lithosphere and the surface and ground water.

The other risk from chemical disinfection process arises if the chemical containing solution is not treated properly at the end. It would be possible for the release of microbes, parasites and viruses, resistant to disinfectants (like Giardia) to the environment. This release of microbes will endanger the community's health.

Improper disposal of electronic equipment like Computers, televisions, lab analysers, EKG monitors in hospitals poses a significant threat, when these electronic products are incinerated or land filled, they can release heavy metals and other hazardous substances that contaminate groundwater and pollute the air. This hazardous material comprises from lead in cathode ray tube (CRT) monitors to chlorinated plastics in cable wiring, brominated flame-retardants in circuit boards and mercury in LCD displays.

If hazardous chemicals like mercury and lead discarded as a waste, they will eventually make their way into the environment where organisms living in rivers, lakes, or moist earth transform it into highly toxic chemicals like organic mercury. This type of chemicals, which affects nerves and brains at extraordinary low levels persists and accumulates in animals, fish and the global environment.

The two main concerns of PVC wastes in the healthcare wastes arise from the two known hazards from Dioxin and DEHP. Dioxin a known human carcinogen, can be formed during the incineration or burning of PVC products polluting the atmosphere and, DEHP a phthalate used to soften PVC plastic that can leach from PVC medical devices, and it is linked to dangers pointing towards reproductive birth defects and other illnesses, according to animal studies (Global south 2007).

2.4.3 Social impacts of health-care waste

Although precise physical limits of the planet are unknown, it is suggested here that the limits to the globe's sustainability for humans are more urgently social than they are physical (Benny Joseph, 2005).

Considering the social issues the social sensibility starts from the disposal of health-care wastes. Quite apart from fear of health hazards, the general public is very sensitive about the visual impact of anatomical waste, which is recognizable human body parts, including fetuses. In no circumstances is it acceptable to dispose of anatomical waste inappropriately, such as on a landfill.

The impact of infection caused by un-proper dumping of HCW in open areas is a practice that can have adverse effects on the population, basically on the scavengers during their recycling practices. This impact on the society, especially in the developing countries, have great stress on the income of the society, comparing the health budget of the poor to be less with that of the personal income.

Main issues like an increase concern of health infection of the society by HIV/AIDS and the acceptance of the society for the patients also can be the major social impact. Since HIV and other communicable diseases can be easily transferred in the poor society, improper disposal of HCW can contribute to the increase rate of these diseases. On top of that these diseases contribute mainly to the loss of the productive labour in the country imposing an impact on the countries economy.

In more general sense the environmental and social issues are directly related with the health impact of health-care wastes.

2.5 Treatment and disposal technologies for HCW

Health-care waste treatment and disposal technologies are the basic part, which needs great concern of design and justification in health care-waste management. Getting a safe and affordable waste treatment and disposal system is much more difficult than tackling the waste segregation problem in a medical area. On top of that the health, environmental and social impact of poor HCW treatment and disposal is becoming the recent issue, which needs a great concern.

Several methods of treatment and disposal are appropriate for infectious waste management depending on the type of waste material. Incineration used to be the method of choice for most hazardous health-care wastes and is still widely used. However, recently developed alternative treatment methods are becoming increasingly popular. Irrespective of the kind of treatment and disposal methods there are two options of running HCW treatment, hazardous HCW can be dealt with in a decentralized manner with each health care facility having it's own on-site system or in a centralized way, in which HCW being transported off-site to a HCW treatment unit that can be located either in a regional referral HCF or in a public / private waste treatment plant (WHO, 1997).

The final choice of treatment/disposal option should be made carefully, on the basis of various factors, many of which depend on local conditions:

- Disinfection efficiency;
- Health and environmental considerations;
- Volume and mass reduction;
- Occupational health and safety considerations;
- Quantity of wastes for treatment and disposal/capacity of the system;
- Types of waste for treatment and disposal;
- Infrastructure requirements;
- Locally available treatment options and technologies;
- Options available for final disposal;
- Training requirements for operation of the method;
- Operation and maintenance considerations;
- Available space;
- Location and surroundings of the treatment site and disposal facility;
- Investment and operating costs;
- Public acceptability;
- Regulatory requirements. (A. Pruss *et al.,* 1999)

Decentralised HCW treatment: The advantages of on-site HCW treatment are situated at the level of convenience and minimization of risks to public health and the environment by confinement of hazardous HCW to the healthcare premises. Decentralized, on-site treatment is often the only feasible solution for rural / remote HCFs and is also advisable when HCFs are situated far from each other and the road system is poor. Disadvantages are that extra technical staff may be required to operate and maintain the systems. It may also be difficult for authorities to monitor the performance of many small facilities: this may result in poor compliance with operating standards, depending on the type of systems, and subsequent increased environmental pollution (WHO 2007).

Centralised HCW treatment: The advantages in choosing off-site centralized HCW treatment solutions are: financially, greater cost-effectiveness can be achieved in larger units unless the running costs for waste collection and transportation remain too expensive; technically, efficient operation and maintenance of units is easier to ensure in a centralized facility than in several plants where financial and human resources may not be readily available; and with respect to legal compliance, conformance to environmental norms are easier to achieve applying more sophisticated/ expensive technology and by the reduced number of facilities that need to be monitored by environmental surveillance authorities. Considering privatisation of waste treatment or disposal facilities has been seen as a desirable option, and this can be achieved more easily on a regional basis than for numerous small units (WHO 2007).

Although off-site/ centralized treatment increases dependency of the HCF on an external actor and requires a fine-tuned transportation system, it has additional advantages like increased and efficient operations can be more easily ensured in one centralized facility than in several plants where skilled workers may not be readily available, insuring modifications or expansions are likely to be less expensive. But as it was mentioned earlier these advantages hold the positive side when best off-site transportation is equally practiced minimizing public health and environmental risk.

In many literatures waste treatment and waste disposal technologies are used interchangeably but for the case of this research paper it is found to be important to distinguish between them. Treatment technologies are those technologies used to reduce the hazard or infection level to the permissible amount and also helps waste volume reduction. Disposal technologies are those used to dispose the treated waste finally, and it is the final option in the waste management route. Since the basics of treating hazardous / infectious HCW is to make sure the level of hazard / infectiousness in the acceptable level, and make leftovers of treatment to follow the non-risk HCW stream, the treatment should precede the disposal method.

Based on the hazard it bears each class of HCW require specific treatment. According to the draft of Ethiopian health-care waste management guide these treatment methods shall include one of the following options or combination of options: steam sterilization, incineration, thermal inactivation, gas/vapour sterilization, chemical disinfection, and sterilization by irradiation, or electromagnetic radiation (John Snow Inc, FMOH, 2006).

In more general form the most common technologies and processes used in health care waste treatment are 1) Thermal 2) Chemical 3) Irradiation 4) Biological processes 5) encapsulation and 6) inertization. Waste disposal mechanisms are mainly 1) Sanitary landfill and 2) Safe burial in hospital premises (DHM, 2000).

2.5.1 Treatment Technologies

The need for treatment technologies emerge from the danger that health-care wastes has on the health, environmental, and social well being of the society. The purpose of treating health-care waste is to change the biological and chemical character of the waste to minimize its potential to cause harm (DHM, 2000).

2.5.1.1 Thermal treatment

Thermal treatment technologies mainly rely on the disinfection power of high temperature. Thermal health-care waste treatment technologies include incineration and wet / dry treatment technologies.

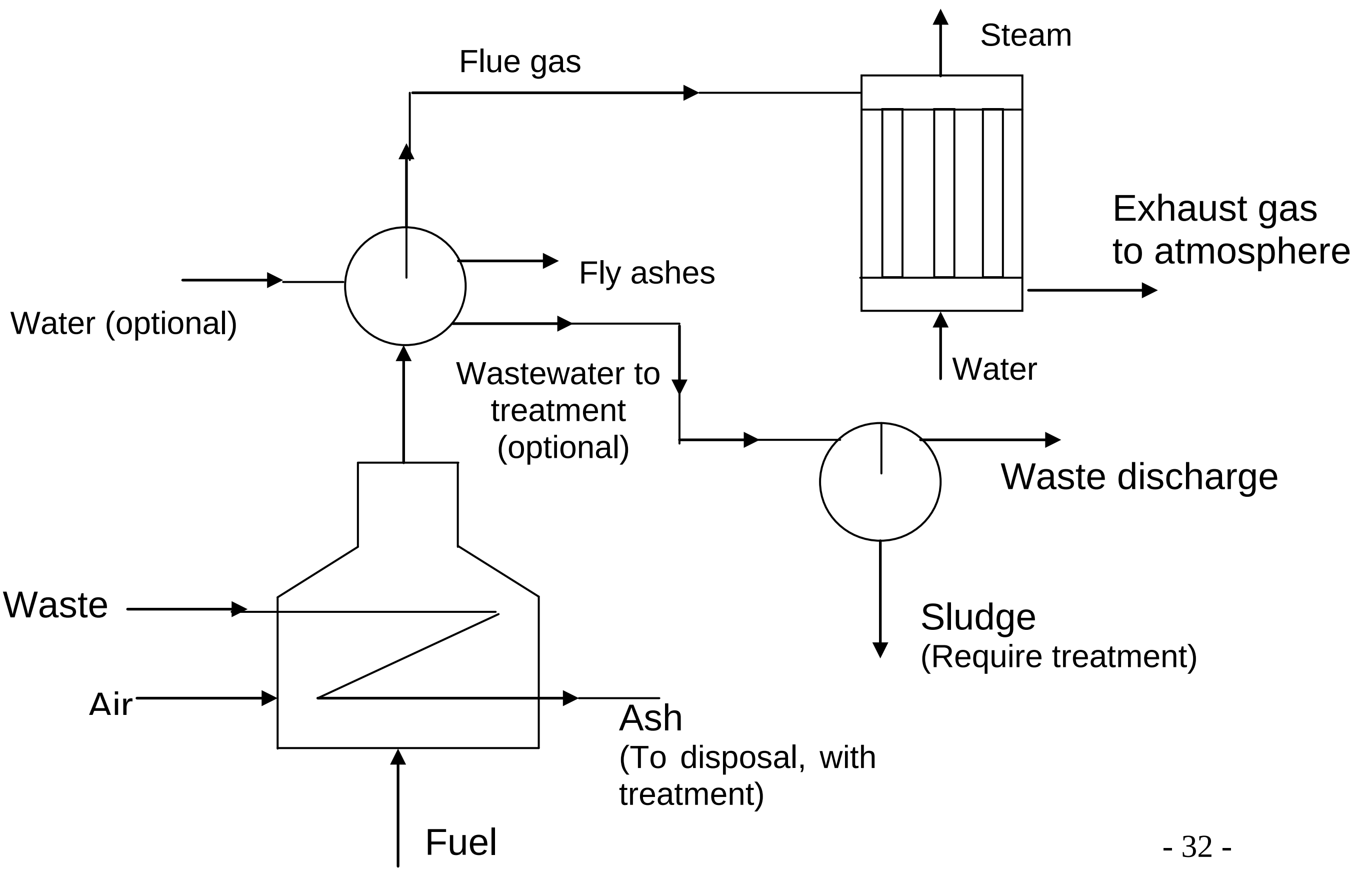
Incineration

Incineration is a high-temperature dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and results in a very significant reduction of waste volume and weight. This process is usually selected to treat wastes that cannot be recycled, reused, or disposed of in a landfill site. The process flow sheet is illustrated schematically in Fig. 2.5.

According to the World Health Organization, incineration of waste is affordable and feasible only if the “heating value” of the waste reaches at least 2000kcal/kg (8370kJ/kg) (A. Pruss *et al.,* 1999) for single-chamber incinerators and above 3500kcal/kg (14640kJ/kg) (A. Pruss *et al.,* 1999) for pyrolytic double-chamber incinerators. The value for infectious waste, for instance, exceeds 4000 kcal/kg A. Pruss *et al.,* 1999). Other characteristics of health-care wastes recommended to be incinerated are wastes having combustible matter above 60%, non combustible solids below 5%, noncombustible fines below 20% and a moisture content of below 30%.

Incinerators can range from extremely sophisticated, high-temperature operating plants to very basic combustion units that operate at much lower temperatures. All types of incinerator, 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 higher temperatures for complete destruction. Higher operating temperatures and cleaning of exhaust gases limit the atmospheric pollution and odors produced by the incineration process (A. Pruss *et al.,* 1999).

Figure 2.5 Simplified flow scheme of incinerators



There are different kinds of incinerators based on their type and size these are Pyrolytic incinerators, rotary kilns, single chamber incinerator, drum and brick incinerators.

Basic waste parameters that should be considered during the planning stage of determining the most suitable type and size of incinerator include studying current extent of waste production and types of health-care waste, estimation of future waste production, knowing the per day (and per bed per day) production rate of incinerable waste and determination of all the physical parameters that determine the suitability of waste for incineration, such as low heating value and moisture content as mentioned earlier.

Pyrolytic incinerators

The most reliable and commonly used treatment process for health-care waste is pyrolytic incineration, also called controlled air incineration or double-chamber incineration.

The pyrolytic incinerator comprises a pyrolytic chamber and a post combustion chamber that functions as follows:

- In the pyrolytic chamber, the waste is thermally decomposed through an oxygen-deficient, medium-temperature combustion process (800 – 900°C), producing solid ashes and gases. The pyrolytic chamber includes a fuel burner, used to start the process. The waste is loaded in suitable waste bags or containers.

- The gases produced in this way, are burned at high temperature (900 – 1200°C) by a fuel in the post-combustion chamber, using an excess of air to minimize smoke and odors (A. Pruss *et al.,* 1999).

Pyrolytic incinerators are adequate for burning infectious waste (including sharps), pathological waste, all chemical and pharmaceutical wastes (including cytotoxic waste), and are not recommended for non -risk health-care waste. Incineration of non -risk wastes in rotary kilns would result on wastage of resources. During the treatment of radio active wastes the radioactive properties of the waste are not affected and may disperse radiation.

In addition to non-risk health-care wastes pressurized container; due to their explosion and damaging risk of the equipment and wastes with high heavy-metal content; for their emission of toxic metals (e.g. lead, cadmium, mercury) into the atmosphere are not recommended for incineration.

Pyrolytic incinerators operating under proper maintenance, are commonly used in hospitals, do not require exhaust-gas cleaning equipment. Their ashes will contain less than 1% un-burnt material (A. Pruss *et al.,* 1999)**,** which can be disposed of in landfills. However, to avoid dioxin production, no chlorinated plastic bags (and preferably no other chlorinated compounds) should be introduced into the incinerator, and should therefore not be used for packaging waste before its incineration.

According to WHO available capacities ranging from 200 kg/day to 10 tonnes/day are available. Mostly hospitals are usually equipped with incinerators with a capacity of less than 1 tonnes/day. Additional exhaust-gas cleaning equipment s are needed for larger facilities.

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.

Comparing on site and off site facilities the technical parameters are described as follows:
On site small-scale incinerators used in hospitals, of capacity 200–1000kg/day are operated on demand. They are manually loaded and de-ashed daily or every 2–3 days; a shovel or a vacuum cleaner should be used to remove the ashes. The combustion process is under automatic control and the services of an operator are therefore required for only part of a working day (e.g. 2 hours).

Off-site regional facilities will have large-scale incinerators of capacity 1–8 tones/day, operating continuously and equipped with automatic loading and de-ashing devices. Incinerators of this size would benefit from energy-recovery systems—at least for preheating of the waste to be incinerated—and exhaust-gas cleaning facilities. It may be possible to use the steam produced to generate electricity. In this case facilities should also be available for the treatment and final disposal of incineration by-products (A. Pruss *et al.,* 1999).

Rotary Kiln

A rotary kiln, which comprises a rotating oven and a post-combustion chamber, may be specifically used to burn chemical wastes, and is also suited for use as a regional health-care waste incinerator. Wastes that are and are not incinerated are the same as that of the pyrolytic incinerators for the same reasons. On the contrary, incineration temperature for rotary kiln is 1200–1600°C. This amount of temperature allows decomposition of very persistent chemicals such as PCBs (poly chloro biphenyls). Unlike that of Pyrolytic incinerators, availability of equipment capacities ranges from 0.5 to 3 tonnes/hour. Exhaust-gas cleaning and ash treatment equipment is likely to be needed, as the incineration of chemical waste produces exhaust gases and ashes that may be loaded with toxic chemicals.

The by products of the waste are evacuated at the bottom end of the kiln. The gases produced in the kiln are heated to high temperatures to burn off gaseous organic compounds in the post-combustion chamber and typically have a residence time of 2 seconds. Rotary kilns may operate continuously and are adaptable to a wide range of loading devices. In addition to these characteristics, equipment, operation and maintenance costs are relatively high, as is energy consumption, wastes and incineration by-products are highly corrosive, and the refractory lining of the kiln often has to be repaired or replaced for this purpose well trained personnel are required (A. Pruss *et al.,* 1999).

Single chamber incinerators

These kinds of incinerator are options that fit minimum requirements, and are recommended when a pyrolytic incinerator cannot be afforded. Wastes that can be incinerated include Infectious waste (including sharps), pathological waste with the limitation of heat resistant pathogens and general health -care waste (similar to domestic refuse having an exceeding heating value of 16740 kJ/kg). Unlike that of pyrolytic and rotary kilns they are incapable of treating pharmaceuticals, chemicals residues and genotoxic wastes.

Radioactive wastes, pressurized containers, halogenated plastics, and wastes with high content of heavy metals are not incinerated in these kinds of incinerators. Incinerator capacity and incineration temperature ranges between 100-200kg/day (A. Pruss *et al.,* 1999) and 300-400 ^{o}c (A. Pruss *et al.,* 1999) respectively.

This type of incinerator treats waste in batches; loading and de-ashing operations are performed manually. Atmospheric emissions will usually include acid gases such as sulfur dioxide, hydrogen chloride, and hydrogen fluoride, black smoke, fly ash (particulates), carbon monoxide, nitrogen oxide, heavy metals, and volatile organic chemicals. Due to this reason this type of incinerator should therefore not be installed where air pollution is already a problem (A. Pruss *et al.,* 1999).

Drum incinerator and brick incinerator

A “drum” or “field” incinerator is the simplest form of single-chamber incinerator. It should be used only as a last resort as it is difficult to burn the waste completely without generating potentially harmful smoke. The option is appropriate only in emergency situations during acute outbreaks of communicable diseases and should be used only for infectious waste.

A “brick incinerator”, for use in similar circumstances, may be built by constructing a closed area with brick or concrete walls. The efficiency of this type of incinerator may reach 80–90% and result in destruction of 99% of microorganisms and a dramatic reduction in the volume and weight of waste. However, many chemical and pharmaceutical residues will persist if temperatures do not exceed 200 °C. In addition, the process will cause massive emission of black smoke, fly ash, and potentially toxic gases (A. Pruss *et al.,* 1999).

Environmental considerations of incinerators

National environmental standards are very important to run incinerators properly with out damaging the environment. Flue (exhaust) gases from incinerators contain fly ash (particulates), composed of heavy metals, dioxins, and thermally resistant organic compounds, gases such as oxides of nitrogen, sulfur, and carbon, and hydrogen halides. If flue gases are to be treated, this must be done in at least two different stages—“de-dusting”, to remove most of the fly ash followed by ''washing '' with alkaline substances to remove hydrogen, halides and sulfur oxides (A. Pruss *et al.,* 1999).

Wastewater from gas washing and quenching of ashes should undergo a chemical neutralization treatment before being discharged into a sewer; the treatment includes neutralization of acids and flocculation and precipitation of insoluble salts. For the separation of acids and alkalis generated during incineration three processes known as wet, semi-wet, and dry are available for the removal of acids such as hydrofluoric acid (HF), hydrochloric acid (HCl), and sulfuric acid (H_2SO_4).

Sludge from wastewater treatment and from cooling of fly ash should be considered as hazardous waste. They may either be evacuated to a waste disposal facility for hazardous chemicals, or be treated on-site by drying followed by encapsulation in drums, which are then filled up with cement mortar and may be disposed of in a landfill. The encapsulation process prevents the rapid leakage of chemicals.

Even though the solid ash left in the incinerator is far less hazardous compared to the fly ash, it is insisted in most countries to dispose it in landfills designed specifically for potentially hazardous substances. Flue gases emerging from the post-combustion chamber has a temperature of about 800°C and must be cooled to 300°C before entering the dust-removal equipment. This is usually achieved in cooling towers, called quenching towers or baths, where the gas is cooled by water circulating in a closed system (A. Pruss *et al.,* 1999). For the removal of particulate matter, cyclone separators, fabric dust remover or electro filters are used according to the efficiency of separation needed.

Wet and dry thermal treatment

Wet thermal or steam disinfection is based on exposure of shredded infectious waste to high temperature, high-pressure steam and is similar to the autoclave sterilization process. It inactivates most type of microorganisms if temperature and contact time are sufficient. For sporulated bacteria, a minimum temperature of 121 ^{o}c is needed and exposure time of 30 minutes. For sharps, milling or crushing is recommended mainly to eliminate physical hazards from needles, render syringes unusable, and reduce waste volume as well as increasing the surface area subject to exposure to high temperature and high pressure steam subsequently increasing the efficiency of the treatment (DHM, 2000).

About 99.99% inactivation of microorganisms may be expected, compared with the 99.9999% achievable with autoclave sterilization. The wet thermal process requires that waste be shredded before treatment; for sharps, milling or crushing is recommended to increase disinfection efficiency. The process is inappropriate for the treatment of anatomical waste and animal carcasses, and will not efficiently treat chemical or pharmaceutical wastes. The disadvantages of the wet thermal process are the following:

- the shredder is liable to mechanical failure and breakdown;
- the efficiency of disinfection is very sensitive to the operational conditions.

However, the relatively low investment and operating costs and the low environmental impact are distinct advantages of the wet thermal process, which should be considered when incineration is not practicable. Once disinfected, waste can join the municipal waste collection and disposal mechanism. The effectiveness of a wet thermal disinfection technique should be routinely checked using the Bacillus subtilis or Bacillus stearothermophilus tests (A. Pruss *et al.,* 1999).

Autoclave

Autoclaving is an efficient wet thermal disinfection process. Typically, autoclaves are used in hospitals for the sterilization of reusable medical equipment. They allow for the treatment of only limited quantities of waste and are therefore commonly used only for highly infectious waste, such as microbial cultures or sharps. It is recommended that all general hospitals, even those with limited resources, be equipped with autoclaves.

The advantages and disadvantages of autoclaving wastes are the same as for other wet thermal processes discussed in this section. The physical requirements for effective steam autoclave treatment are normally different from those required for sterilizing medical supplies. Minimum contact times and temperatures will depend on several factors such as the moisture content of the waste and ease of penetration of the steam. Research has shown that effective inactivation of all vegetative micro organisms and most bacterial spores in a small amount of waste (about 5 – 8kg) requires a 60-minute cycle at 121°C (minimum) and 1 bar (100kPa); this allows for full steam penetration of the waste material (A. Pruss *et al.,* 1999).

Screw-feed technology

Screw-feed technology is the basis of a non-burn, dry thermal disinfection process in which waste is shredded and heated in a rotating auger. Continuously operated units, also called continuous feed augers, are commercially available and already in use in several hospitals. The principal steps of the process are the following:

- The waste is shredded to particles about 25mm in diameter.
- The waste enters the auger, which is heated to a temperature of 110–140°C by oil circulating through its central shaft.
- The waste rotates through the auger for about 20 minutes, after which the residues are compacted

The waste is reduced by 80% in volume and by 20–35% in weight. This process is suitable for treating infectious waste and sharps, but it should not be used to process pathological, cytotoxic, or radioactive waste. Exhaust air should be filtered, and condensed water generated during the process should be treated before discharge (A. Pruss *et al.,* 1999).

2.5.1.2 Chemical disinfection

Chemical disinfection is now being applied for treatment of health-care waste. Chemicals like aldehydes, chlorine compounds, phenolic compounds, etc are added to waste to kill or inactivate pathogens present in health-care waste. Chemical disinfection is most suitable in treating blood, urine, stools and sewage. If possible, wastes should be shredded to increase the extent of contact between waste and the disinfectant by increasing the surface area and eliminating the enclosed space (DHM, 2000). Additionally, shredding helps to render any body parts to be unrecognisable and avoid any adverse visual impact on disposal and to reduce the volume of waste (A. Pruss *et al.,* 1999). However application of this method should only be done when there is no available treatment facility in the area to prevent environmental problems associated with the disposal of chemical residues (DHM, 2000). Some chemical systems use heated alkali to destroy tissue, anatomical parts and other pathological wastes. Wastes from chemotherapy having cytotoxic agents are treated by chemical decomposition.

Microbial resistance to disinfectants has been investigated; due to this reason the effectiveness of disinfection is estimated from the survival rates of indicator organisms in standard microbiological tests. At present, chemical disinfection of health-care waste is limited in industrialized countries. However, it is an attractive option for developing countries, particularly for treating highly infectious physiological fluids, such as patients' stools in case of cholera outbreaks (A. Pruss *et al.,* 1999).

Chemical disinfection is usually carried out on hospital premises. Recently, however, commercial, self-contained, and fully automatic systems have been developed for health-care waste treatment and are being operated in industrial zones. The disinfected waste may be disposed of as non-risk health-care waste, but the chemical disinfectants may create serious environmental problems in case of leakage or after disposal (A. Pruss *et al.,* 1999).

Where relatively cheap chemical disinfectants are easily available on the local market, where there are locally available chemicals, chemical disinfection is an economically attractive treatment option. However, the process is not very popular in developing countries at present, and the choice of equipment is therefore limited.

2.5.1.3 Irradiation

Most micro organisms are destroyed by the action of microwaves of a frequency of about 2450 MHz and a wavelength of 12.24cm. The microwaves rapidly heat the water contained within the wastes and the infectious components are destroyed by heat conduction (A. Pruss *et al.,* 1999). Wastes containing potentially infectious microorganisms (sewage, sludge, biomedical wastes, and waste water) are treated with irradiation technology, which are currently being used in waste treatment operations (DHM, 2000). In a microwave treatment unit, a loading device transfers the wastes into a shredder, where it is reduced to small pieces. The waste is then humidified, transferred to the irradiation chamber, which is equipped with a series of microwave generators, and irradiated for about 20 minutes. Even though the microbial reduction of the system can reach 99.99% the efficiency of microwave disinfection should be checked routinely through bacteriological and virological tests (A. Pruss *et al.,* 1999).

The microwave process is widely used in several countries and is becoming increasingly popular. However, relatively high costs coupled with potential operation and maintenance problems mean that it is not yet recommended for use in developing countries (A. Pruss *et al.,* 1999).

2.5.1.4 Biological process

The process uses an enzyme mixture to decontaminate health-care waste and the resulting by product is put through an extruder to remove water for sewage disposal. The technology is suited for large applications and is also being developed for possible use in agricultural sector. The technology requires regulation of temperature, PH, enzyme level, and other variable. Design application is mainly for regional health-care treatment centre.
Composting and vermin culture as biological processes for treating and disposing of placenta waste, as well as food waste, yard trimmings and other organic waste is also recommended (DHM, 2000).

2.5.1.5 Encapsulation

Encapsulation is one option for pre-treatment before disposal of health-care wastes. The treatment procedure 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 (A. Pruss *et al.,* 1999).

It is appropriate treatment mechanism for 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 (A. Pruss *et al.,* 1999).

2.5.1.6 Inertization

The process of "inertization" involves mixing waste with cement and other substances before disposal in order to minimize the risk of toxic substances contained in the waste migrating into surface water or groundwater. It is especially suitable, for pharmaceuticals and for incineration ashes with a high metal content (A. Pruss *et al.,* 1999).

For the inertization of pharmaceutical waste, the packaging should be removed, the pharmaceuticals ground, and a mixture of water, lime and cement added. The homogeneous mass produced can be transported in liquid state to a landfill and poured in to municipal waste. The process is relatively inexpensive and can be performed using relatively unsophisticated equipment (DHM, 2000). Other than personnel, the main requirements are a grinder or road roller to crush the pharmaceuticals, a concrete mixer, and supplies of cement, lime, and water (A. Pruss *et al.,* 1999). The main advantage of this treatment is its relative inexpensive cost, and its disadvantage is it unfits for the application for the infectious waste.

2.5.2 Disposal mechanisms

Landfill

If there is lack of proper health-care waste treatment before disposal, in the hospital or in the municipality landfill can be regarded as an acceptable disposal route. Rather than allowing the accumulation of health-care waste at hospital or elsewhere, it is recommended to dispose it to the carefully controlled municipal landfill. But even if the risk of disposing elsewhere or accumulating in the hospital premises has higher risk, most municipal land fills are not well designed and controlled. This poor management of municipal landfills would incur its own risk on the community.

There are two distinct types of waste disposal to land, and they are open dumps and sanitary landfills.

Open dumps: are characterized by the uncontrolled and scattered deposit of wastes at a site; this leads to acute pollution problems, fires, higher risks of disease transmission, and open access to scavengers and animals. Health-care waste should not be deposited on or around open dumps. The risk of either people or animals coming into contact with infectious pathogens is obvious, with the further risk of subsequent disease transmission, either directly through wounds, inhalation, or ingestion, or indirectly through the food chain or a pathogenic host species (A. Pruss *et al.,* 1999).

Sanitary landfills: are sites, which are properly designed to keep the waste intrusion to the environment to the lowest level. They are designed to have at least four advantages over open dumps: geological isolation of wastes from the environment, appropriate engineering preparations before the site is ready to accept wastes, staff present on site to control operations, and organized deposit and daily coverage of waste. Disposing of certain types of health-care waste (infectious waste and small quantities of pharmaceutical waste) in sanitary landfills is acceptable; sanitary landfill prevents contamination of soil and of surface water and groundwater, and limits air pollution, smells, and direct contact with the public (A. Pruss et al., 1999).

Safe burial on hospital premises

In remote locations and rural areas, the safe burial of waste on the health-care premises may be the only viable option available at the time. However, certain rules need to be established for the proper health-care waste management. These include:

- Access to the disposal site should be restricted to authorised 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 health-care waste should be buried. If general health-care waste were also buried on the premises, available space would be quickly filled-up.
- Large quantities (>1kg) of chemical/pharmaceutical waste should not be buried.
- The burial site should be managed as a landfill, with each layer of waste covered with a layer of earth to prevent odour, as well as to prevent proliferation of rodents and insects.
- Burial site should not be located in flood prone areas.
- Hospital ground should be secured (eg. fenced with warning signs).
- The location of waste burial pit should be downhill or down gradient from any near by wells and about 50 meters away from any water body such as rivers or lakes to prevent contaminating source of water.
- Health-care facilities should keep a permanent record of the size and location of all their on-site burial pits to prevent construction works, builders and others from digging in those areas in the future.

2.6 International agreements and national policies

The government must implement the goal and Principles governing environmental policies by the appropriate environmental legislation. The goal of any instruments used in environmental policy is to limit the ecological damage caused by production and consumption of good or any service delivered to remedy the problem after occur.

Environmental law is based upon three principles:

- The prevention principle,
- The polluter pays principle, and
- The cooperation principle (D. Joseph et al., 1973)

The prevention principle is the guiding principle of environmental policy. The preventive use of appropriate measures is intended to minimize hazards to human health and prevent environmental damage from occurring.

In its original version, the polluter pay principle stated that any one who contaminates or damage the environment is responsible for the costs of the contamination and the damages. Since the contaminant emission sources of the environment are different and which may not contribute to the main pollution the polluter pays principle has its own weakness. The polluter pays principle is not principle that is primarily concerned with avoiding environmental damage rather the polluter pays principle allows pollution by some individuals, the costs of which must be paid for by the public. The polluter merely pays fees that are intended to induce him or her to limit the environmental damage he or she causes.

The cooperation is based on the nation that conflict can be resolved by the involvement of all affected parties. An attempt should be made to negotiate for the adoption of certain environmental quality goals, e.g., with the result of voluntary self-restraints instead of government mandates. The cooperation principle is also applied in the relations between the federal government and the states. In legislation, the principle is embodied by the provision in the law for public hearings. (D. Joseph Hagerty et al., 1973)

Government initiative towards environmental protection and infectious waste management is increasingly showing progress in the past five years. This initiative can be reflected by continuous measures taken through the past years, from accepting international conventions to formulating action plans.

Basel convention on control of trans-boundary movements of hazardous waste and their disposal adopted on 22, March 1989 was the measure convention that Ethiopia signed to implement. This convention clearly classifies clinical wastes as one of the hazardous wastes under annex VIII number A4020. In addition to this, the convention states the obligation of each party and the measures that should be taken in to consideration during trans-boundary movement and disposal of hazardous wastes mentioned in the convention. Upon accepting international conventions different local policies and guidelines were formulated.

The Ethiopian environmental policy, which was formulated in April 2, 1997, states sectoral and cross-sectoral environmental policies. Under this policy sub article 3.7 classified as human settlement, urban environment and environmental health, the contribution of giving high emphasis on having improved environmental sanitation leading to sustainable development is clearly stated. On this sub article the need of sanitation and priority towards having good waste collection and safe disposal facilities is well underlined.

Environmental impact assessment proclamation number 299/2002 can be taken as the basic proclamation in defining the impacts that any development activity has on the environment. Supporting the idea of preventing and controlling environmental pollution, proclamation number 300/ 2002 states the obligations that any waste generator has and the responsibility of any participating party on municipal waste management and hazardous waste management. To implement the legal statements the ministry of health prepared draft national guide lines for the health-care waste management. In addition to these efforts the government proposed strategic plan of action for hospital infectious waste management system after undertaking preliminary assessments on different sample hospitals in the city.

The budget allocation for the purpose of health-care waste management is low in many hospitals. The study done by ministry of health on four selected hospitals shows that the budget allocated for the purpose of waste management in each hospital was found to be bellow 2 % (FMOHEHD, 2004).

Chapter three – Materials and Methods

3.1 Methodology

The research includes both the qualitative and quantitative approaches. It uses the main principal research methods such as; site observation, literature review, application of questioner, interview and measuring or quantification survey were employed. Both primary and secondary information were used as a source of data. Primary data was gathered to generate the basic information utilised in the research and secondary information were referred from existing documents in order to support the out puts of the research analysis.

Site observation

At the beginning of the study period, different health-care centres was visited inorder to limit the scope of the study and select the proper health-care centres which can represent the major health-care waste generators. During the time of information gathering site observation were undertaken inorder to evaluate the health-care waste management schemes in different facilities, to critically understand the major sources of waste generation, to identify the causes of impacts arising from the waste, and to assess and evaluate the solid waste disposal in the facility.

Literature review

The basic information available behind health-care waste impact, health care-waste management and disposal was reviewed from the existing documents and literatures. Additional secondary data were gathered with the help of literature review technique, to support the research outputs.

Questionnaire and interview

Questionnaires were distributed to different health-care centres including Specialised hospitals, general hospitals, higher clinics, health posts, medium and small clinics in different districts of Addis Ababa. The aim of the questioner was to gather qualitative information about the recent health care waste management, treatment and disposal from skilled personnel's (like: Doctors, nurses, sanitarians) and semi-skilled or unskilled personnel's (like: cleaners and scavengers). For these two different groups two different types of questioners were designed (See annex 2). These questioners have different ways of elaboration to the perspective group. The target of the questioner was to help evaluation of health-care waste management in the city, to assess the impacts arise from the current health-care waste management and disposal scheme in the city.

In addition to the questioner developed there were an in-depth interview with different concerned personnel's in order to support the findings of the questioner. Basically the interview concentrate on the missed and ambiguous information on the questioner and it helps to clarify the ambiguity.

Quantification survey

The primary data was the main backbone of the research and it was conducted for one week on the five systematically selected hospitals. It helps to estimate the extent of the disposal problems, the amount of generation, the waste composition and the potential of energy generation from the waste.

3.1.1 Sample centre determination

Sample centres are determined by using cluster-sampling method. The need for this approach merged from the field visit of different health-care centres. Sample centres are selected based on the criteria of:

- Kind of service delivery (Specialised, general), assuming that the waste generation rate relies on the kind of service that the centre delivers.
- Owner ship of the centres (Governmental and private), assuming that the waste generation depends on the type of waste management policies of the institution.
- Percentage of service delivery (number of beds in the facility), assuming the generation of health-care waste to be directly proportional with the rate of service delivery
- Capacity of waste generation (being major source of solid health-care waste), since hospitals are the major health care waste generators they are selected.

3.1.2 Collection and sorting of health-care waste

To collect the solid waste generated, sample beds are selected based on two-stage cluster sampling. Depending on the type of ward settings and number of bed in every facility, the sample beds are selected. The way of sample collection in different health-care centres taken in the study are discussed below.

The ward settings for the case of St. Poulos specialized hospital, St. Peter specialised hospital and Bethezatha general hospital is similar. Since each ward in the mentioned hospitals have different rooms with the same number of bed, sample rooms are taken from each ward as base. Then the waste from the beds of the sample rooms are sorted manually and weighted for seven days. Even though the ward setting of Zenbaba general hospital is similar to the above group, due to less number of beds in the hospital the wastes from all the beds were sorted at generation point and weighed for one week.

The ward settlement for the case of Menilik II specialised hospital is different from those of the other hospitals. Each ward in Menilik II specialised hospital has a continuous distribution of beds. It doesn't have any separated rooms; all beds in the ward are contained in one specific big room. Due to this reason sample beds are randomly selected and the wastebaskets are spotted with a specific mark. To gather the quantitative data, the waste from these baskets are collected separately, weighed and sorted each day for consecutive seven days.

In order to help sorting of solid wastes for the case of this research, the WHO categorization for health-care wastes, draft of hospital waste management national guideline of Ethiopia and information found during field inspection were used as base. The wastes are primarily categorised in to Infectious and non-infectious waste. Infectious wastes include sharps (needles, infusion sets, knives etc), plastic wastes in need of special care (Plastics holding different fluids, chemicals and medicines), wastes from patient care purposes (Bandages, gloves), anatomical waste (if there is no pit in the vicinity). The other category for non-infectious waste is similar to general wastes and includes food debris, recyclables like uninfected plastics, paper, metal and glass.

3.1.3 Inventory data analysis

In this research work, quantitative and qualitative data analysis approaches have been applied to address the issues in question. The quantitative approach is the weight of waste generated in every sample bed and the qualitative is the information collected using the questioner.

Quantitative data analysis

The solid waste weight data collected and sorted from selected hospitals is analysed to determine the generation rate of the health-care waste in each hospitals, to estimate the health-care waste generation in the city and to classify the waste percentage generated in the hospitals. To estimate the generation rate in the city, the sample mean of the waste generated in the selected hospitals is used and for the confidence level of 90% the standard error as well as the margin of error is calculated. Calculating sample means for each kind of waste in every hospital the percentage composition of wastes is evaluated.

Qualitative data analysis

The raw data collected from the randomly distributed questioner was evaluated and interpreted for the purpose of predicting the possibility of expected impacts to occur. Even though most of the information found using questioner is discussed qualitatively, some information is converted quantitatively in to percentage of positive or negative responses over the number of total respondents.

The above analysis's help to easily identify the health-care waste management methods, proper treatment mechanism which are suitable for the hospitals in the city and assess if there is any possibility of energy recovery from the waste treatment.

3.1.4 Materials and instruments

The materials and instruments used during the study time include:

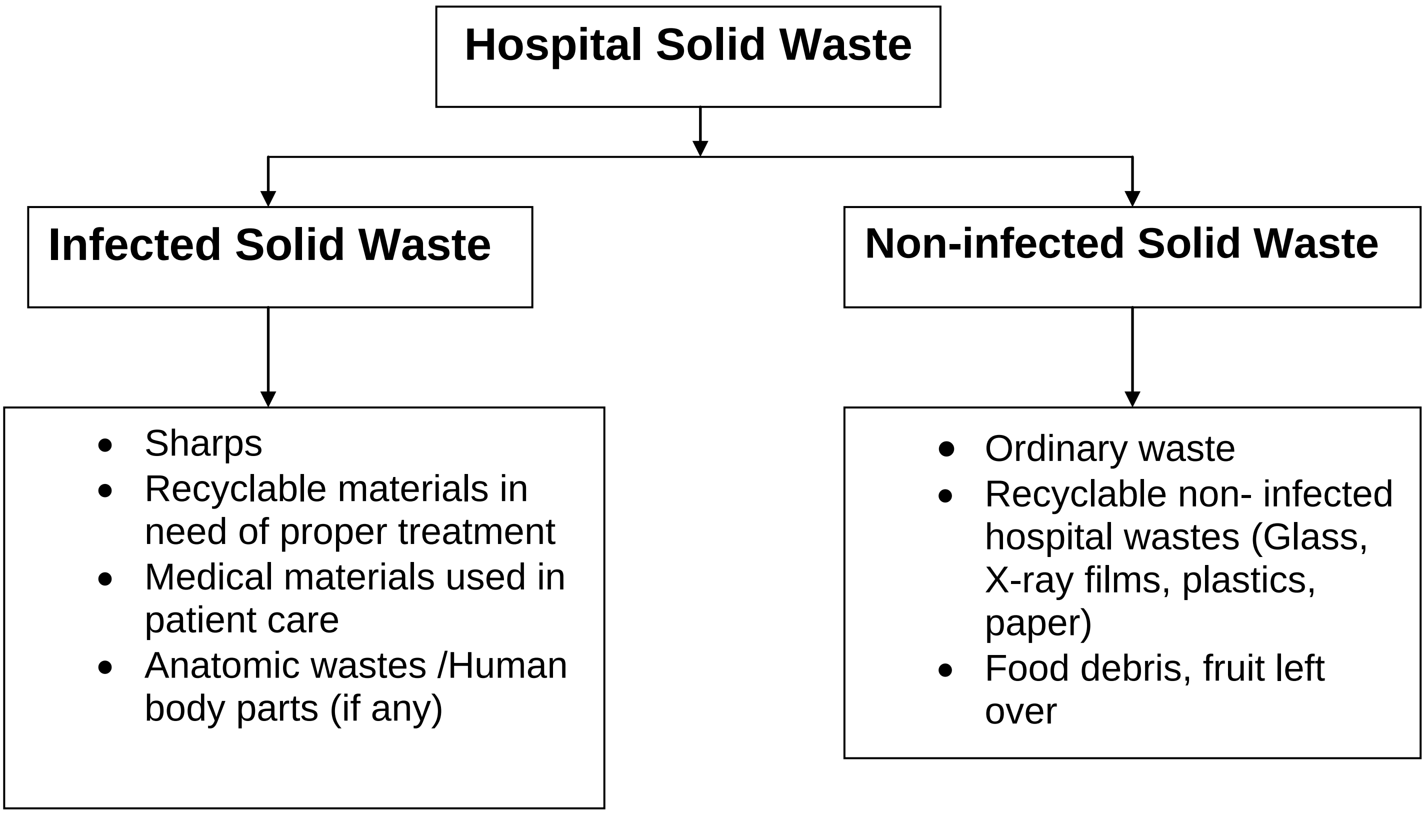
a. Hand protective rubber gloves;
b. Mouth kits and protective overcoat
c. Different color plastic trash buckets for waste collection
d. Self balancing weighting scale that is accurate to 1/1000 Kg measurement

e. Sorting hook for separating different waste types to their different categories
f. Different color plastic bags
g. Digital cameras for taking images of waste management trends at different health-care center samples

Chapter Four- Analysis and Discussion

Waste collection for sampling purpose was dependent on the trend of health-care waste management in every hospital. Samples were collected in every twenty-four hours for one week. Even though there is slight variation in waste type between the specialised hospitals and general hospitals, the waste composition were found to be the same. From the repetitive hospitals that were visited during the study time, it was observed that the solid wastes generated from all of them have sharps, recyclable materials in need of proper treatment (plastic holders, like glucose and other fluid plastics plastic holders), wastes of medical materials used for patient care purposes (gloves, bandages, soaked clothes or cottons), food debris (fruit leftovers), ordinary wastes (dust, soil), and recyclable materials that are not infected (paper, x-ray films, plastic holders). As mentioned in chapter three, based on the repetitive observation made to the health-care centre, general classification of WHO and draft of health care waste management national guide line of Ethiopia, the solid waste was classified in to two main categories, Infected and non- infected health care wastes, and for the case of this research the wastes are classified as shown in diagram 4.1.

Figure 4.1 Solid waste classifications in health-care centres



In most cases anatomic wastes or discarded human body parts are separately disposed to isolated pits but during field visit in some health care centres it was observed that disposal of this wastes follows the disposal root of general waste. The amount that surveyed in this research only considers the anatomic waste that follows the root of general waste. The waste data collection sheet was developed based on the type of wastes and it was developed to suit the collection purpose in each weekdays. (See Annex 3)

4.1 Estimation of waste generation rate

To assess the extent of impacts from health-care waste in the city, the very early work that should be done is estimating the generation rate of solid health-care waste in the city. For the case of this research three different methods of waste estimation procedures were taken as a choice. The first method of estimation is, taking all the hospitals in the city and measuring the overall waste generated during a given period of time, then extrapolating the result for needed period of time, which is for one day, one week, or to the yearly bases. Using such a method helps to estimate the generation rate to the best accuracy, but it is difficult to classify the waste composition since it needs segregation at the disposal site. Since it is not recommended to segregate the waste at the end of the waste disposal root this method is not used. The second method is measuring and evaluating the weight generation rate of sample beds in selected sample health-care facilities and extrapolating the result to the city for needed period of time. This method is based on the statistical way of analysis to evaluate the health-care waste generation rate of the city. Since sample beds are used for estimation purpose the classification of the waste composition can be done at the HCW generation site. And the variation range of estimated health-care waste is evaluated by applying confidence intervals. The third method is by gathering visual estimation for generation rate of health-care solid waste or expertise evaluation for different health-care centres and extrapolating this value for the city. Since the third method needs high experience of expertise judgement in the area and has high personal errors, it is expected to have less accuracy and difficult to rely on.

Taking aforementioned factors into consideration, the second method was found to be more appropriate for the application in this research work.

Assumptions for the method

- The major health-care waste generators in the city are the specialised and general hospitals and this was supported by field observation.
- Out of the major solid waste generating health-care centres, based on the amount of bed occupancy rate hospitals owned by Ministry of health and the city government contribute much of the waste.
- The type of solid waste generated in different hospitals was almost the same and this was proved during field visit in different health-care facilities.
- The main generation centers in the hospitals are patient bed rooms and specialised departments.
- The waste generation rate was assumed to follow approximately a normal distribution curve.
- The bed occupancy rate was estimated from previous two-year bed occupancy rate data.

For the purpose of health-care waste estimation sample hospitals was taken using cluster sampling method based on service delivery. Two clusters having a total of five hospitals consisting of 60% specialised governmental hospitals and 40% general private hospitals was assigned. The sample hospitals include Minilik II specialised hospital, st Peter specialised hospital, st. Poulos specialised general hospital, Bethzatha general hospital and Zenbaba general hospital. The representative hospitals are assigned to each cluster using judgment-sampling method, by considering the constraint of time and cost of data collection. The sample bed selection for all hospitals was done using random sampling in the way that suits the ward arrangements of each hospital. The sample beds taken from each hospital and the total occupied bed in the hospital is presented in table 4.1

The mean waste generated in sample hospitals for each day of the week was summarised as shown in table 4.2. The mean values of solid HCW collected in each sampling day for the sample hospitals is manipulated in the graphical form as presented in annex six. (See Annex 4)

Table 4.1 Sample beds and occupied beds of sample hospitals in sampling week

Health-care centre	Number of sample beds taken (Sample size) = n	Occupied beds (population size) in the week =N
Minilik II specialized hospital	21	148
St. Paulos specialized G. hospital	29	240
St. Peter specialized G. hospital	24	80
Bethzata General hospital	6	33
Zenbaba General hospital	4	4
Total	84	505

Table 4.2 mean HCW generation rate in each day for sample hospitals in Kg/bed.day

Health-care centre	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Minilik II specialized hospital	0.77	1.02	0.50	0.66	0.51	0.88	0.99
St. Poulos specialized G. hospital	1.92	2.48	1.42	1.93	1.51	1.47	1.89
St.Peter specialized G. hospital	0.67	0.70	0.20	1.02	0.90	0.60	0.59
Bethzata General hospital	1.17	1.39	1.25	1.32	1.22	1.27	1.38
Zenbaba General hospital	1.54	1.67	4.50	1.72	1.89	1.98	3.58

Estimation of Mean solid HCW generation in sample hospitals: Taking the results from table 4.2, which was found by taking the mean of health-care wastes collected from each sample beds during the sampling period, the mean for each hospital is calculated using formula 4.1. These mean generation rates are given in Kg/bed/day for each hospital, and revised in table 4.3.

Formula 4.1

$$\text{Mean value for hospital “ y ”} = \left(\sum_{i=1}^{i=7} \text{Mean waste generation for day “ i “ of hospital “ y} \right) / 7$$

Where " i "stands for number of days of sample collection.

Sample calculation is performed using formula 4.1 for Minilik II specialised hospital (MSpH) as follows:

$$\text{Mean HCW generation rate for (MSpH)} = \frac{0.77+1.02+0.50+0.66+0.51+0.88+0.99}{7}$$

$$m_{minilik} = \underline{\underline{0.761}} \text{ Kg/bed.day}$$

Table 4.3 Mean generation rates for sample hospitals in Kg/bed/day

Health-care centre	Mean waste generation in Kg/bed.day " m "
Minilik II specialized hospital	0.761
St. Poulos specialized G. hospital	1.805
St.Peter specialized G. hospital	0.669
Bethzata General hospital	1.286
Zenbaba General hospital	2.410

Estimation of Mean solid HCW generation rate for the city: The total mean of solid HCW generation rate for the sample hospitals can be calculated by taking sum of the product of mean values for each hospital with its own bed distribution. Using the mean values of each hospital presented in table 4.3 and formula 4.2 the estimate for the mean solid HCW generation is calculated as follows:

Formula 4.2

$$\text{Total mean value for sample hospitals " M "} = \sum \left(\text{Mean waste generation of hospital "y"} \ \mathbf{X} \ \text{bed distribution of Hospital " y "} \right)$$

$$\mathbf{M} = \sum m_y \times \mathbf{P(y)}$$

The bed distribution for sample hospitals can be calculated by dividing the number of sample beds in the respective hospitals by the sum of all sample beds, which are 84. The fractional values found by this method are the bed distributions of the respective hospital. Applying the above method the bed distribution for the respective hospital is calculated and presented in table 4.4

The total mean of solid health-care waste "M" for the city is calculated as:

$$\mathbf{M} = (0.761X0.25) + (1.805X0.35) + (0.669X0.29) + (1.286X0.07) + (2.41X0.05)$$

$$= 0.19025 + 0.63175 + 0.19401 + 0.09002 + 0.1205$$

$$= 1.227 \text{ Kg/bed/day } (1227 \text{ gm/bed.day})$$

The standard deviation of the mean solid HCW generation rates for the sample hospitals is found by applying formula 4.3

$$\text{Standard deviation of the mean solid HCW}(\delta) = \sqrt{\left(\left(\text{Mean waste generation of hospital "y"} \right)^2 X \left(\text{Sample bed distribution of hospital "y"} \right) \right) - \left(\text{Total mean value for sample hospitals "M"} \right)}$$

$$\delta = \sqrt{\sum (m_y^2 \, X \; \mathbf{P(y)}) - \mathbf{M}^2}$$

$$= \sqrt{(1.821 - 1.227^2)}$$

$$= 0.562$$

Taking the standard deviation, since the sample size is (> 30), for 90% confidence level the confidence interval for the total mean is given by ± 0.4505δ and that gives the result to be ±0.253.

The total mean solid health-care waste generation rate for the sample hospitals, (for the purpose of this research assumed to be the Addis Ababa solid HCW), lies in the range of 1.2265 ±0.253 Kg/bed.day.

Assuming that the specialised hospitals to represent most of the governmental hospitals and using the same procedure since the sample bed amount is 74 which is greater than 30 the solid HCW generation rate is found to lie in the range of 1.141± 0.241 kg/bed.day. On the contrary since the sample beds taken for private general hospitals is (<30), applying small sampling methods, the solid HCW generation rate for private hospitals was found to fall in the range of 1.735 ± 1.009 Kg/bed.day. The overall discussions made above are summarized in table 4.4 for the result of total solid HCW generation rate. The same analysis result for the governmental and private hospitals is tabulated and presented in annex five (See annex 5).

Summary

- Estimated solid HCW generation rate of Addis Ababa = 1.227 ±0.253 Kg/bed.day.
- Estimated solid HCW generation rate of specialised hospitals (Governmental hospitals) = 1.141 ± 0.241 Kg/bed.day
- Estimated solid HCW generation rate of General hospitals (Private hospitals) =1.735 ± 1.009 Kg/bed.day

Estimation of total solid HCW generation rate for the city in Kg/day: The estimation of waste generation rate for the city can be found from the product of mean of solid HCW generation in the city (in Kg/bed.day) and the total beds estimated to be occupied. The total beds, estimated to be occupied in the year 2006-2007 is estimated from the past two years bed occupancy rates found from Federal ministry of health (FMOH). Since the bed occupancy rate of the past two years, which are 2004-2005 and 2005-2006, shows inverse relation with the population growth in the city. For this research purpose simple linear regression is assumed and used to predict the expected bed occupancy rate. The data used to predict expected bed occupancy rate for the year 2006-2007 is given in annex six (See Annex 6). Applying the above procedures, the estimated bed occupancy rate was found to be 32 %. Multiplying the bed occupancy rate by the total expected beds in the city; by the end of the year 2006-2007 (which is 4258 beds) the total occupied beds per day in Addis Ababa would be 1,363. These values are shortly presented in table 4.4.

Table 4.4 Mean solid HCW generation rate for all sample hospitals

All sample Hospitals						
Health-care centre	Mean of sample waste generation in Kg/day. bed	Number of sample beds taken (Sample size) = n	Total occupied beds (population size) in the week =N	Sampling distribution for all sample hospitals	(Mean) X (Sample distribution)	$(Mean^{2})$X Sample distribution
Minilik II specialized hospital	0.761	21	148	0.25	0.190	0.145
St. Poulos specialized G. hospital	1.805	29	240	0.35	0.632	1.140
St.Peter specialized G. hospital	0.670	24	80	0.29	0.194	0.130
Bethzata General hospital	1.286	6	33	0.07	0.090	0.116
Zenbaba General hospital	2.410	4	4	0.05	0.121	0.290
Total		84	505			1.821
Mean of waste generation for sample hospitals						1.227
Standard deviation of sample						0.562
Margin of error for 90% confidence interval= ±						0.253
Mean value Kg/day.bed=						1.227±0.253
Estimated bed occupation rate in %						32
Total estimated Bed Occupation in the city						1,363

The overall waste generation rate of solid HCW for the city in Kg/day is calculated by:

Overall waste generation rate in Kg/day of A.A "**M** $_{A.A}$" = (Mean waste generation of A. A in Kg/bed.day **X** Occupied bed per day in A.A "**B**")

$$M_{A.A} = M \times B$$

$$= 1.227 \text{ Kg/bed.day} \times 1{,}363 \text{ bed}$$

$$= \underline{\underline{1{,}672}} \text{ Kg/day}$$

Applying this estimation to find the weekly and yearly solid HCW generation rate in Addis Ababa the weekly and yearly generation rates are found to be 5,668.74 kg/week and 295,786.76 Kg/year ≈296 tones/year.

Summary

➢ Daily solid HCW generation rate for Addis Ababa	= **1,672.4**	Kg/day
	≈ **1,672**	Kg/day
➢ Weekly solid HCW generation rate for Addis Ababa	= **11,706.8**	Kg/week
	≈ **11,707**	Kg/week
➢ Yearly solid HCW generation rate for Addis Ababa	=**610,844.5**	Kg/year
	≈ **611**	tones/year

4.2 Composition of solid HCW in Addis Ababa

As discussed earlier in the previous sections, for the purpose of this research paper solid health-care wastes are classified into two main categories as infectious, wastes containing biological contaminants or other hazardous materials and non-infectious which are those similar to general wastes. The two categories are further classified into different waste categories and this categorization was done to fit the waste composition of the visited health-care centres in the city. Based on this classifications wastes are sorted on the site of generation and the results found for each sample hospital was tabulated in table 4.5

Table 4.5 waste compositions in percent for sample hospitals

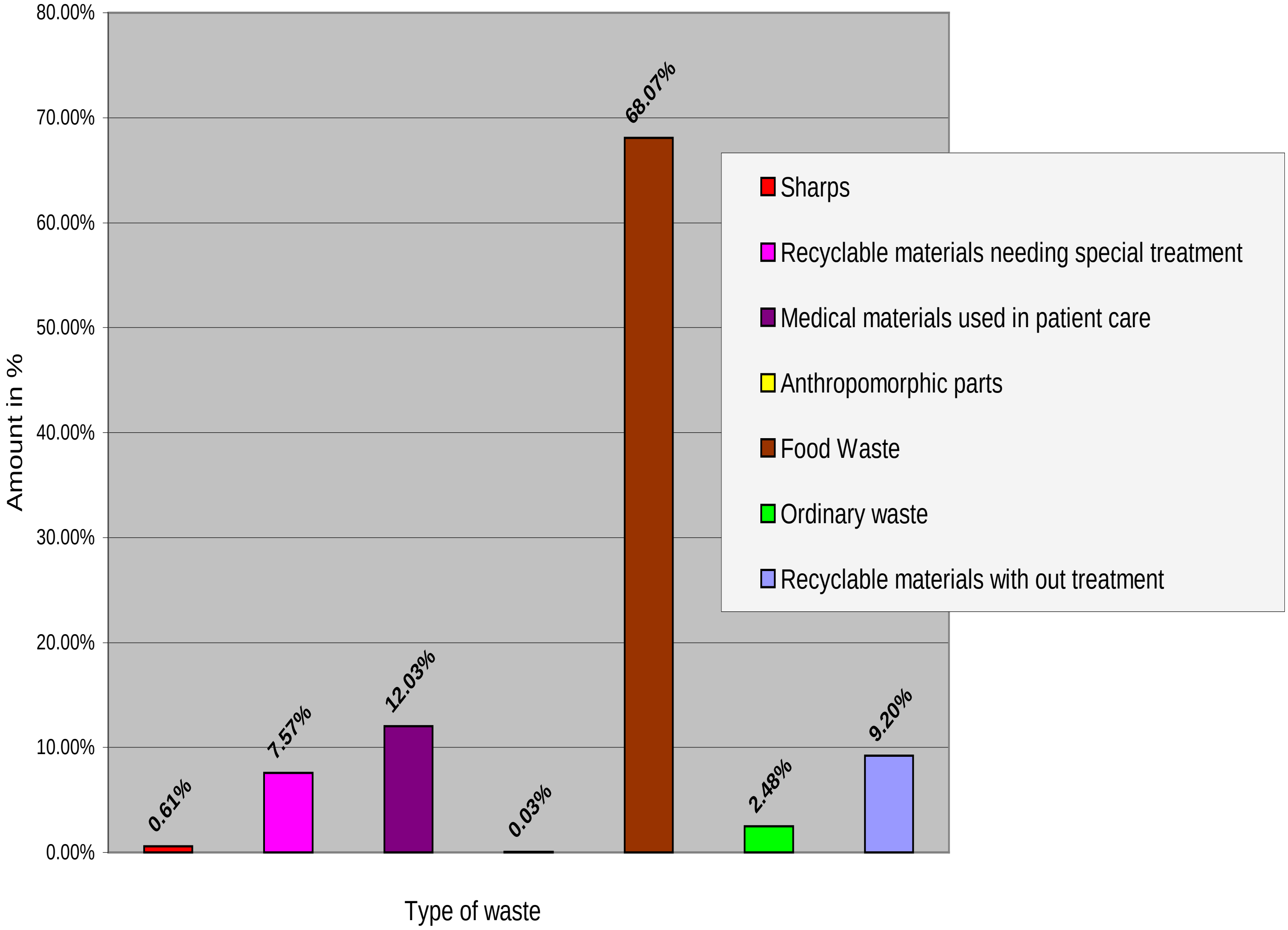
Waste distribution in sample health-care centres								
Health-care centre	**Sharps**	**Recyclable materials needing special treatment**	**Medical materials used in patient care**	**Anthropomorphic parts**	**Food Waste**	**Ordinary waste**	**Recyclable materials with out treatment**	**Total**
Minilik II specialized hospital	0.505%	5.457%	7.851%	0.206%	78.662%	0.387%	6.931%	100.00 %
St. Poulos specialized G. hospital	0.465%	6.147%	10.531%	0.001%	74.097%	2.812%	5.947%	100.00%
St.Peter specialized G. hospital	0.92%	6.193%	8.509%	0.000%	73.183%	2.239%	8.956%	100.00%
Bethzata General hospital	0.428%	17.034%	29.742%	0.000%	34.166%	5.892%	12.739%	100.00%
Zenbaba General hospital	1.249%	15.059%	20.642%	0.000%	29.068%	1.784%	32.198%	100.00%

The percentage values in table 4.5 are graphically presented in annex seven to help visualise the variation between the different wastes. The data in table 4.5 are found by measuring the amount of specific waste in each day then evaluating the mean values for the sampling days, and taking the weight percentage of this mean values over the total waste generation mean rate of the respective sample hospital. The overall solid HCW classification for the city was evaluated by, calculating the means of each waste type in all sample hospitals and taking the weight percentage of each waste. The values of these waste percentages are tabulated in table 4.6 under the respective waste type.

Table 4.6 Composition of solid HCW in Addis Ababa

Health-care centre	Sharps	Recyclable materials needing special treatment	Medical materials used in patient care	Anthropomorphic parts	Food Waste	Ordinary waste	Recyclable materials with out treatment	Total
Waste amount in % for all sample hospitals	0.61%	7.57%	12.03%	0.03%	68.07%	2.48%	9.20%	100%
Waste amount in % for all sample specialised H.	0.56%	6.03%	9.64%	0.04%	74.79%	2.24%	6.71%	100%
Waste amount in % for sample General hospitals	0.88%	15.94%	24.69%	0.00%	31.33%	3.61%	23.55%	100%

Figure 4.2 Solid waste compositions in % for all sample hospitals



The graphical representation of waste classification for all sample hospitals is presented in figure 4.2. The graphs for the specialised and general hospitals are placed in annex eight. Taking the assumption that the composition of solid HCW in the city to be the same (supported from field visit) the mean values for all sample hospitals represents the waste composition of Addis Ababa.

The result of table 4.6 and figure 4.2 shows that, if good waste segregation was practiced in all hospitals, the amount of infected waste in the city falls to be 20.24 %, of which 7.57 % of the waste to be recyclable needing very special treatment for recycling. The rest of the wastes, which is 79.76 %, are general waste type that can be disposed as ordinary waste type. Considering the existence of good waste segregation at generation point, 9.2 % of the general waste can be reused or recycled with out any special treatment by the hospitals or by other small scale recycling organizations. From the total HCW in the city 16.8% of the waste is recyclable and reusable out of this recyclable material 76% is plastic materials.
Both the infectious waste and the recyclable wastes in the city are graphically presented in figure 4.3 and 4.4.

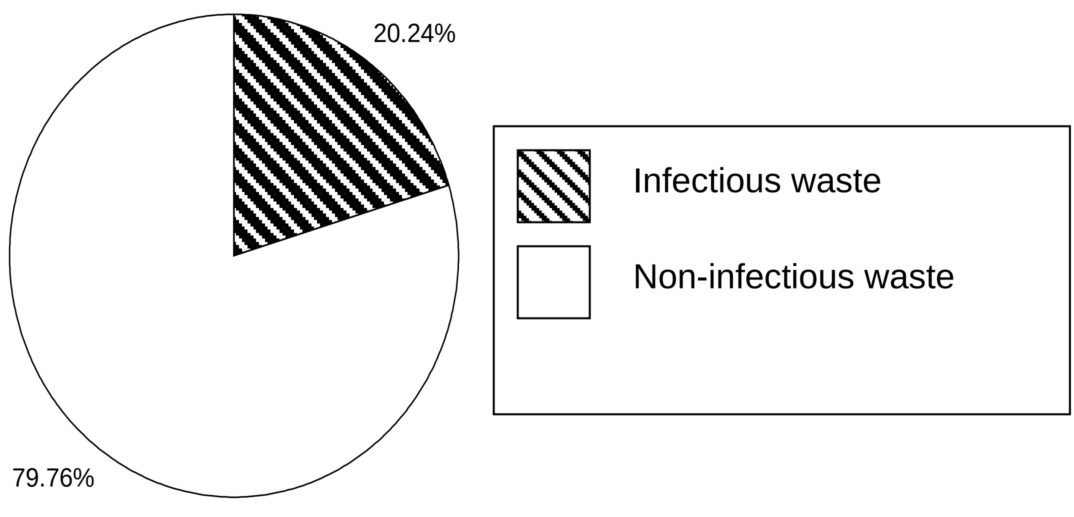


Figure 4.3 Contaminated/ infectious waste in % for sample hospitals

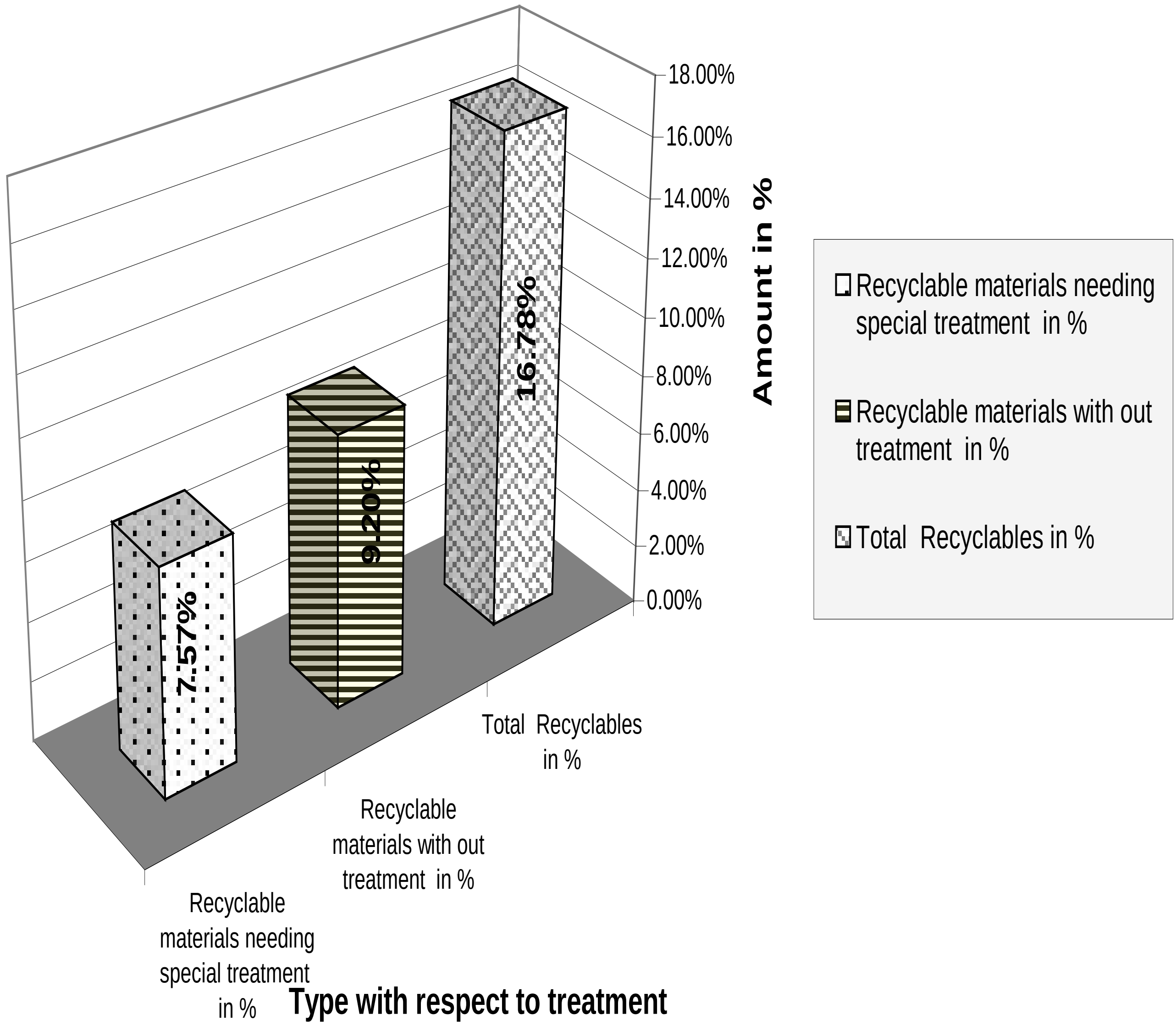


Figure 4.4 Recyclable materials in % for all sample Hospitals

4.3 Treatment plant and possibility of heat generation

Depending on the waste classification, the application of treatment mechanism varies. According to the major classifications of health-care wastes infectious wastes need proper treatment before disposal. The non-infected health-care wastes can be disposed as one of municipal waste type, if and only if proper segregation is in practice.

The main problem in the present health-care waste treatment is that, since the waste segregation at source are not well organized and practiced the load on the treatment plant makes the treatment to be inefficient. Site observations, interviews and questionnaires result revealed that some portion of the mixed waste find its way towards the present main treatment, which is brick incineration or open burning. This mixed waste consists of mainly sharps, wastes from health-care purposes, obsolete medicines and recyclable materials (infected or uninfected plastics in excess). The main problem observed rather than lack of awareness and negligence resulting poor segregation is that the work load on the sanitation staff and lack of having clear work distribution. In all visited health-care centres the whole waste management treatment and disposal task falls on the same team, making the task laborious and results carelessness.

Recently two governmental hospitals are on the process of purchasing and commissioning incinerators having 50 Kg/ hr burning capacity. But for health-care wastes, based on the type of waste, different types of waste treatment mechanisms should be practiced. If proper segregation is in practice, general wastes (like ordinary wastes and food wastes) can be treated in the same way as that of communal wastes, which is land filling. The special care that should be considered is that the municipality should separate the land filling area from the ordinary communal waste damping area either by fencing and guarding or by implementing new sanitary landfill only for hazardous wastes. Un-infected recyclable wastes should be segregated and further processed for other purpose or can be used in hospitals for different uses as an example the hard glucose bags can be used as a substitution for safety boxes and can be used for encapsulation containers. Since more than 75% of the recyclable material is plastic recycling and reusing would save the environment from accepting the most non-degradable waste. In addition to this since the whole recyclable material takes 16.78 % (Infected plus un-infected) of which 213.3 Kg/day is plastic, recycling of this amount of plastic has a total price sells of 1,492.95 Br/day (The recent sells price of plastic scrap in “Merkato” varies from 6-8 Br/Kg).

Regarding infectious HCW in the city, three types of treatment mechanisms are possible ways if proper segregation is practiced. Recyclable materials that needed special treatment needs steam sterilization or autoclaving and can be recycled or reused. Since most of the recyclable material is plastic, the application of incineration for these types of wastes leads to air pollution by dioxins. This percentage of recyclable waste weighs only 126.6 Kg/day (out of which 96.2Kg/day is plastic), for this amount of waste it is possible to use small size on-site autoclaves. Amputated anatomical parts should be treated by biological degradation in controlled pit. Other infected wastes mainly from patient care purposes, infected paper and closes should be treated by controlled off-site incineration. The main reason of choosing incineration as a treatment plant is mainly from the nature of health-care wastes and operational costs. According to the WHO the heating value of infectious waste is 4000 Kcal/Kg (16,736 KJ/Kg), which is above the minimum feasible heating value (2000 Kcal/kg, 8370 KJ/Kg) for the application of incineration as treatment. Practicing off-site incineration helps the effectiveness of treatment capacity for infectious waste in the city. By minimizing the treatment workload on the cleaning staff and the health-care centre; it enhances the improvement of segregation and proper waste management practice. From the point of environmental pollution control the city benefits a lot from not having many point pollution sources. The need of having central offsite treatment plant in expertise opinion is inevitable. Out of the questioned 50 experts 100% agreed on having standardised recycling, sanitary land filling and central controlled incineration treatment plant for different waste types.

Using the estimated bed occupation rate, wastes that needed incineration have an average weight of 211.84 Kg/ day. But if all the beds of health-care centers in the city are occupied, which is the case of maximum infectious health-care waste generation, the maximum amount of infectious waste (M_{inf}) generated in the city is calculated to be:

$$M_{inf} = (12.67 \text{ X } 1.227 \text{ Kg/bed/day X } 4258 \text{ Beds}) / 100$$
$$= 661.95 \approx \underline{\underline{662 \text{ Kg/day}}}$$

The bed occupancy rate for the city reaches hundred percent in rare cases, Due to this reason the occurrence of maximum solid waste generation rate is rare. Compare to the previous year’s experience, the average bed occupancy rate was observed to be 32% and this shows the occurrence dates for the maximum waste generation rate is below half of the days in the year. Taking the maximum amount of infectious waste generated, the 50 kg/hr central incinerator can operate for 13.2 hrs, which is above the specification. Due to this reason the central incinerator should have a capacity more than 83 kg/hr for eight hours operation or applying the two incinerators already in process of purchase for the city is another option. These shows the two incinerators that are in process to be implemented in the city are more than enough for the treatment of the infected waste generated in the city recently.

The minimum average energy per hour (Eave) generated from the incineration of the waste is calculated as follows:

$$\text{Eave} = (211.84 \text{ Kg/day X } 16{,}736 \text{ KJ/Kg}) / 13.2 \text{ hrs/day}$$

$$= \underline{\underline{268{,}587 \text{ KJ/hr}}}$$

Assuming the loss of energy to be negligible, which is the ideal case, the amount of steam that can be generated with this amount of energy can be calculated by the following formula:

$$\text{E ave} = (\text{m X } C_{water} \text{ X } \Delta T) + (\text{ m X } h_{vap})$$

$$= \text{m X } ((C_{water} \text{ X } \Delta T) + h_{vap})$$

Using this formula and assuming the inlet conditions of the water to the heat exchanger to be at standard temperature and pressure, the initial temperature is 23^{o}C (= 296 K) and the final temperature is assumed to be saturation temperature of water, which is 100^{o}C (=373 K). Applying these assumptions the amount of steam generated per hour "m" is

$$\text{m} = 268{,}587 \text{ KJ/hr } /((4.121 \text{ KJ/Kg K X } (373\text{-}296) \text{ K}) + 2261.5 \text{ KJ/Kg})$$

$$= \underline{\underline{104.2 \text{ Kg/hr}}}$$

(Source for C_{water} and h_{vap}: Robert H. Perry & Don green, 1984)

The calculated amount of steam is much less than the minimum amount of steam generated in medium capacity steam boilers, which is 45,359 Kg/hr. Even though the amount of steam generated is small for high-energy generation, it can be used for steam sterilization of recyclable health-care wastes. Another option of using the energy from the waste can be for the purpose of pre-heating the waste to be incinerated.

4.4 Impact assessment of health-care waste disposal in Addis Ababa

Waste minimization

The trend of solid HC waste minimization in observed governmental hospitals was poor compared to that of the observed private hospitals. To reduce the solid waste in the private health-care centres different foodstuffs having the probability of leftovers (e.g. fruits, packed foods etc) used for patient visiting purpose are not allowed to inter the health-care vicinity. This rule helps the private health-care centres to reduce their percentile generation rate of general waste compared to that of the governmental hospitals. As shown on table 4.6 the food waste generation of governmental hospitals was observed to be 74.79% compared to that of all the waste generated per bed in the governmental hospitals. On the contrary the food waste generated in the private hospitals was observed to be 31.33% of the overall waste generated per bed in private hospitals.

Recycling and reusing of materials that are not used for health-care purpose are not well organised and formally practiced in all hospitals. During the study period it was observed that informal reusing of plastic and paper materials by the cleaning and disposal staff is practiced. Since this recycling is not well organised and controlled the risk of infection and poisoning by chemicals is high. If there was proper reuse and recycling of materials in the health-care centres, at least 9.2 % of the waste that discarded recently can be saved as a resource than being a burden on the environment. Since 7.57% of the total generated waste is recyclable waste that has direct contamination with body fluids and some chemicals the need of proper segregation is inevitable inorder to apply recycling. Out of the overall recyclable waste generated in the observed health-care centres, the majority of the waste was plastic material used as containers.

Segregation of health-care wastes

Theoretically health-care waste segregation is the basic step for proper HCW management. During the field visit of the study period, the proper signs for good health-care waste segregation, like applying coloured waste bins for different wastes, having proper waste bins containing international marking symbols, having no chance of waste mixing, and awareness towards segregation among the workers was examined. In this period the lack of solid waste segregation at the generation point was proved by lack of having coloured separated waste bins and lack of properly designed waste bins. In addition to this, out of the five sample hospitals only two hospital has well designed and with internationally symbolised safety boxes for sharps. From the visited hospitals, one hospital (20%) use three yellow bin system for health-care waste segregation. But the solid waste segregation in this hospital is poor due to lack of awareness in the hospital community towards segregation.

High mixing of health care wastes was observed, in all hospitals. Even though there were safety boxes in the two hospitals out of the five samples (40%), there was mixing of sharps with other wastes due to negligence of medical staffs, and shortage of safety boxes. The results from questionnaires revealed that 49.3% of the respondents agreed as the trend of segregation in the city's health-care centres to be poor. In addition the interview with the cleaners shows the risk of infection during waste collection to be high, causing occupational hazard on the cleaning staff. The main reasons for this poor segregation was discovered to be lack of awareness from cleaners and supportive staffs, lack of having proper waste handling materials, negligence of medical staffs and poor follow up of the mandated personnel.

Figure 4.5   Sample mixed waste in an existing waste bin.

On site waste collection, storage and transportation

In all hospitals the waste collection schedule was in the permissible range of the standard time of collection set by world health organization. In all visited health-care centres solid waste is collected from eight to twelve hours of generation. But the method of collection by the cleaners is poor due to negligence and lack of awareness, which exposes them to be affected by different diseases. Unavailability of proper protective materials like heavy-duty gloves, aprons, protective shoes and masks is another difficulty for having proper onsite collection. The waste bins, which are used for primary collection, are not well designed for the purpose of solid health-care waste collection, and most of them have no cover and even if they do, their cover does not fit properly. While this study was carried out, it was observed that in all hospitals except one (80%), the cleaning staffs wear normal gloves used for patient care purpose, and in all hospitals the apron and shoes for the cleaners is not as per the standard, due to this reason the exposure towards occupational hazard is high. In all observed hospitals there were cleaners who faced puncture from improperly disposed sharps. There was no labelling of waste bins showing the waste generation point during disposal and there was no reserve waste bin for emergency cases.

Most visited hospitals in the city have no primary solid waste storage area. Out of the five sample hospitals only one (20%) hospital has primary storage. The primary storage area for this hospital was the dressing room for the sanitation staff, and it does not fulfil the health and occupational safety standards for primary storage. In all governmental health-care facilities the secondary storages are the normal communal bins prepared for the disposal of general wastes. Since there is no solid waste segregation in the health-care centres around Addis Ababa highly infectious wastes find their ways to these normal type communal bins. Additionally the site visits to the health-care facilities revealed that the secondary storage was grossly inadequate and the waste was found littering all over the place. The scavengers further scatter the waste causing dispersion with in the premises and facilitate the transmission of communicable diseases.

Figure 4.6 Sample secondary storages communal bins in the governmental health-care centres in Addis Ababa (Left) and scavenging cat in secondary storage area under one of the sample hospitals visited (Right).

Transportation of waste from the generation point to the secondary storage (communal bins) with in the vicinity of health-care centres is facilitated by the sanitation staff using either by manual carrying or by the help of four wheel trolley. The transportation materials for on-site purpose are not continuously cleaned and are not properly designed for the purpose of carrying HCW and cleaning. This problem and manual carrying of wastes attract vermin and expose the health-care centre workers (mainly cleaners) to communicable diseases. Even though it was difficult to find data that shows the exposure of cleaners to communicable diseases, the 50 professionals from 18 hospitals in the city judge the risk of exposure for the cleaners in the respective health-care centres to be 23%, which has maximum value compared to those of other groups that are expected to be at risk around health-care centres (See annex nine). Out of the 30 randomly selected cleaners of the five sample hospitals that participate in interview 26 gave positive answer towards being caught by communicable diseases from poor on-site waste storage and transportation.

Off-site transportation of waste

Health-care waste in Addis Ababa is being transported just like the ordinary domestic and commercial waste that is transported from the municipal solid waste collection centres. The "loaders" load the health-care waste spread around the secondary storage area manually on the municipal waste collection trucks and this has an impact of spreading communicable disease. The trucks recently used for collecting the health-care waste in Addis Ababa do not satisfy the standards set by world health organization (WHO). Since these trucks in the city are not well designed for health-care purpose, the chance of spill from the trucks is high. The open trucks used for collection can be considered as one contributor to solid health-care waste dispersion and environmental pollution.

Treatment and disposal

Treatment and disposal of solid HCW is the final step of solid waste management in health-care centers. All visited health-care centers during the study time has final treatment facility. The treatment and disposal facility for all hospitals in Addis Ababa was observed to follow the same trend. Most health-care centers (hospitals, higher, medium and small clinics) in the city uses brick incinerators and open burning as shown in figure 4.7. But in some health-care centers for reusable materials other treatment mechanisms like chemical disinfection and sterilization are in practice.

(a)

(b)

(c)

Figure 4.7 Open burning site in one of the hospitals visited (a) brick incinerator with out proper chimney (b) and with out proper designs (C).

All brick incinerators used in visited health-care centers are not well designed for the purpose of on-site treatment. These brick incinerators are not ergonomically designed. In most cases the wastes are feed to the incinerator using manual lifting. The height of the waste inlet for most brick incinerators in the city is almost above 1.6 m, which is above the chest of medium sized person. All brick incinerators do not have temperature-controlling devices, which help to maintain the temperature of complete combustion. The area and placement of ash withdrawal doors are not suitable for cleaning purposes. In some health-care centers the capacity of incinerators are not enough compared to the waste generation frequency and rates of ash withdrawal in the health-care center. The chimney of brick incinerators is too short in some health-care centers causing inversion in the facility and some incinerators do not have stacks (see figure4.7 (b) and (c)). Due to the above design problems the final incineration treatment facilities in the city are observed to be poor and considered as one of the sources for environmental pollution (like air pollution from smoke coming out of short stacks) and infection during disposal time in the health-care centers.

The sanitation of treatment materials “in this case incinerator” is poor in all health care centers. There is no scheduled cleaning of incinerators. Due to the negligence of some workers and poor design of the treatment unit the waste entering the incinerator is not well managed and observed to be scattered around the area. In most governmental hospitals the ash from the incinerators is damped in open areas around the incineration point. The poor sanitation of the treatment plant in the visited health-care centers was observed to cause loss of aesthetic values, attract vermin (insects) and scavengers becoming main sources for leachate around the treatment plant.

In one out of the visited hospitals the incineration machine used for treating needles at each ward or waste generation unit reduces the risk of puncture and infection due to sharps. (See fig 4.8)

Figure 4.8 On-site needle incinerator

Using the solid waste categorization for the purpose of this thesis, the waste expected to be incinerated is found to be 20.24 % and include sharps, contaminated solid wastes from health-care purposes and anatomical waste (if there is no pit in the HC). And the rest of the wastes are expected to be recycled or follow the route of general waste disposal. But since there is no proper segregation in all health-care centers, the wastes to be incinerated include pressurized containers and plastics, which cause explosion risk and emission of dangerous gases like dioxins.

Expertise judgment for solid waste management and disposal around the visited health-care centers revealed that the recent disposal method fulfills only 63.7% compared to that of the proper disposal mechanism. Even though this expertise opinion result shows a “good” level according to the rating method used in the questioner, the visual inspections around these health-care centers proved that the disposal facilities need improvement all over the city. This poor solid waste management in the city is increasing the workload on the incineration plants by imposing wastes that should not be incinerated, causing emission of incompletely combusted gases to the environment and increasing the risk of explosion. As an example, incineration of pressurized medical wastes causes damage on the incineration plant as shown in figure 4.9.

Figure 4.9 Damaged brick incinerator due to explosion from pressurized waste incineration

Most of the waste that considered as general waste from health-care centers, which is around 79.76%, is disposed to the municipal land fill area. This waste amount expected to include mainly recyclable materials that do not need special treatment (paper and plastics mostly), food waste, and ordinary waste. But most of the infected wastes found their way to the municipal dumping sites. In one governmental specialized hospital it was observed that, due to lack of placenta pit the placenta was disposed to the communal general waste bin in the health-care facility. In most visited health-care centers sharps and clothes used for patient care purpose having different body fluids were disposed to the general waste landfills. The food debris disposed to the communal bin was observed to be contaminated with different body fluids. But the scavengers around the disposal area use different wastes as income generation and source of food.

Nature of Impacts

The main impacts of poor solid HCW management and disposal that was observed during the study time are mainly environmental, health, and social. Environmental and health impacts are direct impacts of poor solid HCW and social impacts are indirect impacts resulted as a consequence of direct impacts.

The expertise evaluation collected by questioner shows different percentage. Taking the three impact types to have 100 % of total contribution the health, environmental and social impacts has 37.7, 35.6, and 26.7% impact contribution respectively. This rating shows that the health and environmental impacts fall in the same range with slight difference. This shows the main impacts in solid health-care management, treatment and disposal to be health and environmental impacts, which entail slight social impact.

The main environmental impacts observed during the study period are:

a. Impacts of solid HCW on Air (Micro climate hazards, generation and dispersion gaseous contaminants from burning of wastes)
b. Impacts of solid HCW on land (Soil contamination around disposal sites)
c. Surface water contamination
d. Odor around in disposal sites
e. Loss of clear site due to the smoke around treatment and disposal areas.

The burning of health-care waste especially plastic and infected waste release hazardous gases which poison's human health as well as affects the ecological resources causing air pollution. Incineration or open burning coupled with weather conditions, population density around the health-care center, congestion and malnutrition of people is observed to further aggravate the respiratory disease and allergies among the public in the disposal site. The release of incombustible gases, dust particles, and hazardous gases from health-care waste burning are seriously affecting the health of human being, which is difficult to quantify since no data is available and appropriate health surveys have not been conducted in this area.

Impacts on land are mainly caused during collection, storage, transportation, treatment and disposal, due to dispersal of solid wastes in the route of waste management. Since the disposed wastes contain heavy metals, pharmaceuticals, and infected wastes, the leachate from this waste around the storage and disposal site was observed to be an impact on land. The ash deposited around the incineration plants is the main source of land pollution.

The only probability of water pollution caused by solid HCW is due to leachate from the poor disposal of the health-care wastes around the disposal area and from the leachate of ashes around the treatment or burning sites. This leachate may result in contamination of mainly surface water with heavy metal and infectious wastes.

The observed health impacts were infections through puncture, abrasion or cut in the skin (Leading to HIV, Viral hepatitis and other infections), Infection through inhalation and ingestion and exposure to toxic, corrosive, flammable, reactive chemicals or pharmaceuticals. Since there was no well-organized data collection on health impacts in all observed health-care centers, these impacts are only supported by expertise opinions.

The social impacts found to be of positive and negative type. The positive impact is due to retrieving of recyclable waste items and providing income generation opportunities for the low-income poor people. From the opinion gathered and performed interviews it was magnified that the most exposed workers in the health-care centers and disposal area was found to be workers in disposal route (Janitors, Cleaners & scavengers), due to this reason the negative social impacts are mainly reflected on this group. The negative impacts observed were loss of fitness for their job and loss of income due to illness caused by solid HCW. Incapability to wards affording the cost of health is the other social issue, since most of governmental hospitals cover half of the health costs and none of the visited private health-care centers observed to cover for health costs of these groups, the cost for health problems caused by solid health care waste on these personnel and their family (due to transmission of disease) is burden of life. Since some of the workers are family supporters the loss in income of these workers affects the family they support. The other observed social impact was from the cultural point of view, disposal of body parts in an open area was not found acceptable. This disposal of body parts (where there is no pits) is causing poor esthetic value.

Chapter Five- Limitations and suggested future work

During the sampling time in some health-care centers it was observed that the patients mix the wastes of different beds. The short time frame of all hospitals for waste collection causes the possibility of incorporating additional health-care centers to be challenging. The high mixing of health-care waste makes the proper sorting for the purpose of laboratory work to be dangerous. Since most of the collected wastes are mixed with the infectious waste, performing laboratory work for determination of calorific value is substituted by secondary data found from WHO. Finally the main bottleneck for the research work was the scarcity of fundamental existing works in the field of study. Lack of having enough previous works around health-care waste management makes the research to start from the scratch.

From the results of the research paper and the methods used it is believed that further works in the field of health-care waste impact assessment and management should be performed. In the future works additional health-care centers especially other than hospitals shall be incorporated; proper designs and impact assessment for the central health-care waste treatment plant shall be performed.

Chapter Six- Conclusion and recommendation

6.1 Conclusions

i. Health care waste sources

The field visits and the questionnaires result revealed that the health-care centers in Addis Ababa have poor solid waste management and disposal. The main HCW generators were observed to be the governmental hospitals due to the number of beds they have and the number of patients they serve. In these major generators waste segregation, onsite and offsite collection, transportation, storage, treatment and disposal are poor. In the research on hospitals, main sources of waste generation sites were identified to be patient wards, cooking kitchens and specialist departments.

ii. Solid health-care waste classification and estimation

In the research the solid health-care wastes are broadly categorized into infectious and non-infectious. For the case of composition estimation the solid infectious waste further classified into sharps, recyclable materials those need special treatment (like sterilization), wastes from patient care purposes and discarded body wastes (If there is no pit). The non-infectious waste is classified in to food wastes, food debris, ordinary waste and recyclable material with out treatment.

The percentage composition for infectious waste generated in the city was estimated to be 20.24% and the percentage of non-infectious wastes is found to be 79.76%. For the sample hospitals the percentage of infected solid waste varies from 14-47 % depending on the number of beds in the facility. The total mean waste generated in the city from health-care centers were estimated and found to be 809.82 kg/day. Using this calculation, if proper segregation is practiced in health-care centers in Addis Ababa the infectious waste amount that needs treatment is calculated to be 163.9 kg/day. The analysis of gathered data indicates that 16.78% of the total waste is recyclable; of this amount 9.20% can be directly recycled or used without further sterilization and the rest 7.57 % of the waste needs treatment before recycling.

iii. **Health care waste management**

During the study time, main participants in the health-care waste collection; storage, transportation and disposals are figured to be cleaners, on site treatment plant workers and waste loaders to waste collection trucks. The contribution of work related professionals and the whole hospital community towards waste segregation and proper waste management is found to be poor.

1. Waste segregation and storage

The solid health-care waste segregation at generation point is poor in the city. Even in some hospitals where there are different types of waste containers for different types of wastes at source, segregation of waste is little due to either, lack of awareness towards the need of segregation or lack of continuous follow up.

The major problems arising from the lack of segregation at source is the wide spread contamination of general wastes causing the amount of the contaminated waste to be high. Since all infected wastes are incinerated at on-site burning or incineration plants, an increase in the amount of contaminated waste due to poor segregation suppresses the capacity and efficiency of existing poor treatment plants. Lack of segregation at generation source reduces the amount of recyclable and reusable resources allowing the process of scavenging at disposal sites. In some hospitals anatomical wastes or body parts are not segregated from general wastes and observed to follow the same root due to lack of disposal pits.

The waste containers used to receive and store waste in health-care establishments in the city are not specially designed for the purpose and results in the mixing of infectious and general wastes and hampers segregation of recyclable components. Although different sized bags are provided for different types of waste in some institutions, there is no standardization of waste containers or plastic bags. In one of the visited hospitals the three bin system is followed but none of the bins are observed to have the proper type of waste. Minor health-care establishments in the city use common waste bins for all types of waste.

All visited hospitals use central open communal type bins for secondary storage. Most of the time the capacity of these bins were not enough for the generated waste amount before collection time. At most hospitals the central storage area is poorly managed and scavenged by the waste handlers, waste loaders and different animals. In most health-care centers this storage site are unsightly and unhygienic.

2. Primary and secondary collection

The main participants in primary collection in the health-care centers are mainly cleaners. Since there is no work distribution between the cleaners, all the cleaning, collection and disposal work lies on the shoulder of the same group. Collection materials for on site purpose are not the standard type and are not supplied on time for the workers. In all the visited health-care centers the off site solid waste collection is facilitated by municipal waste collection service or privately owned municipal solid waste collecting firms. From the generated health-care wastes only a small amount is incinerated onsite and the rest, as a mixed waste, is collectively transported along with municipal solid waste to municipal open damping area.

In some hospitals dedicated collection is not practiced. No special vehicles are used in any of the health-care centers. Due to poor follow up the collections are generally unreliable and this brought load on the secondary storage areas. Leakage of contaminated waste and dispersion of debris from collection vehicles could be sources that create environmental and health problems to the community.

3. Treatment and Disposal

The main treatments in use for solid wastes in the city are open burning and incineration in brick incinerators. Both treatment methods are uncontrolled burning systems, which found to be useful only in emergency cases. The visited treatment plants used for solid health-care waste are poor compared to the standard treatment methods or incineration methods. The existing onsite treatment plants do not fulfill the proper criteria for good environmental pollution prevention and public health. Most of the visited health-care centers use the municipal landfill area as disposal site for their general waste. Since there is no segregation of health-care waste in the city, the general waste disposed to this landfill area is contaminated and mixed with infectious wastes like sharps and wastes soaked with body fluids.

Controlled sanitary landfill does not exist in the city, due to this reason there is no special area for solid health-care waste disposal. During the study period it was observed that scavenging and poor recycling by the neighborhood poor society in the landfill site “Koshe” was observed.

4. Capacity of treatment plant and possibility of energy recovery

Assuming all the beds in the health-care centers of city to be occupied, the maximum infectious solid health-care waste generation rate is found to be 662 kg/day. Based on this information, the minimum capacity of the central treatment plant should be 83 kg/hr. Taking the minimum heat value for infectious waste the minimum energy per hour was calculated to be approximately 269 MJ/hr and this amount of energy generates only 104.2 kg/hr of steam at standard temperature and pressure. This amount of steam generated is below the minimum steam generation rate of medium steam generators.

5. Health, Environmental and social impacts of poor management and disposal

The impact assessment for the health-care waste management and disposal in the city revealed that the main impacts are health, environmental and social. The field visits and expert opinions reflect that health impact has slightly higher compared to environmental impact. Both health and environmental impacts bring about social impacts.

The health impact that arises from health-care waste occurs at all the management and disposal routes. The main causes for health problem are identified to be infection due to puncture, abrasion or cut in the skin (leading to communicable diseases like HIV/AIDS), infection through inhalation and ingestion and exposure to different chemicals.

The main environmental impact occurs at the end of solid waste management and disposal route. The main environmental impacts are figured out to be air, land and water pollution. Air pollution mainly occurs at the end of waste treatment by the generation of smoke from treatment incinerators. In addition to this the odor from the disposal site is the other air contamination. Land or soil contamination occurs in all waste management routes, which are collection, transportation, and disposal due to waste dispersion. The only probability of surface water contamination was observed to occur at the disposal site due to leachate from the solid waste and the ash from the incinerators.

And finally the assessment result shows that the social impacts like loss of job and insecurity of workers and their families towards health cost coverage is the result of both the health and environmental impact.

6.2 Recommendations

i. National Policies

The national effort towards improving national approaches of hazardous waste management including health-care wastes shall be activated. Even though there are supportive policies towards having clean environment the need of having proper national guideline towards health-care waste management is important. National action plans shall be prepared, implemented and revised in regularly planned manner. Appropriate legislation that gives mandate to specific governmental institution shall be introduced to control proper health-care waste management and treatment. It is preferable to give the mandate to one institution with the necessary support and resource, in order to monitor the health-care waste management and treatment at every health-care centers in the city.

Integrated cooperative participation of the private institutions, NGO's and the community shall be enhanced. An assessment on different impacts shall be performed before health-care establishment.

ii. Awareness development

The lack of awareness towards health-care waste management in the city is the main bottleneck in implementing proper health-care waste management. Health care professionals, administration, supportive staffs and the sanitation staff should get proper training towards developing good health-care waste segregation and management.

The results of field visits show that the lack of awareness is posing danger to the health of waste handlers and the community around the health-care disposal sites. Due to this reason developing the awareness of the community on the impacts of health-care wastes will increase the participation of the community towards having improved national health-care waste management.

iii. Health-care waste management

For the health-care centers in the city the health-care professionals, administration and the whole health-care community should participate in the waste segregation feeling belongingness. The health-care center administration should develop its own health-care waste management policy and enforce the implementation. In addition it should budget enough amount of money in order to supplement the hospital community with proper training, support the sanitation staff in delivering the standard protective materials on time, assess; evaluate and control the overall waste management and disposal in the health-care center.

In order to help effective health-care waste management and disposal in the city, short and long term measures should be implemented in the future.

Short term recommended improvement measures

- Minimization of health-care waste on generation point shall be practiced in every health-care center. As an example since all hospitals prepare food for the patients every day, forbidding the incoming food from visitors decreases the major contributor of the health-care waste. In addition to this purchasing materials with less quantity of waste like packaging materials reduce solid health-care waste.
- Health-care professionals should be motivated to play an important role in solid-waste segregation at the generation source. In segregation, adequate double lined color-coded plastic bags with proper cover allowing solid waste entrance shall be placed at the generation sources.
- Standard safety materials for sanitation staff shall be readily purchased and regularly delivered, in order to reduce the health and social impacts. Every health-care center should assign separated and controlled primary solid health-care waste storage area (rooms) nearby the generation sources.
- Three or four wheel trolley, easily cleanable, preferably designed to have different compartments should be made available for each solid health-care waste generation source.

- Secondary storage areas should be protected from scavengers, and it must be covered. The communal bins used as secondary storage should be emptied or replaced continuously and regularly when the waste reaches one third of its volume.
- Since open burning and brick incineration are point sources of environmental pollutions, on site selection and controlling of incinerating time for perfect dispersion should be studied and implemented. Until a central treatment is installed the two incineration plants that are on the way of implementation can be used as off site incineration plants for nearby hospitals, since both plants are located near to the center of the city and most of the hospitals are located around the center of the city both can be used as temporary treatment plants for the city. By this mechanism the two treatment plants can operate with full capacity every day covering all or part of the operational costs covered by the health-care centers, which apply them. The ash from the incinerating plant must be collected and disposed to the landfill covered with plastic bags in order to limit leachate to the ground.
- For the short term implementation the offsite transportation can continue with the same kind of trucks keeping that the volume of the communal type bins collected are full only until three fourth of its volume and covered properly either with plastic canvas or the bins shall be modified to have good cover. This at least reduces the spill of solid health-care waste during transportation.
- The municipality should separate and assign specific area for solid health-care waste in the existing open damping area until implementing new well designed sanitary landfill. Specific area should be selected in the existing landfill site where the reach of children and scavengers is forbidden and far from the existing neighborhood. This segregated area should be used only for the purpose of solid health-care waste disposal and must be guarded against intrusion and access by unauthorized people.

Long-term recommended improvement measures and further studies

- To help effective health-care waste management in the city the city government must coordinate the co-operation between health-care centers, NGOs, private sectors and the community.
- Each health-care center should assign well-designed, easily cleanable, refrigerated and controlled secondary storage area.
- The offsite solid health-care waste transportation trucks for Addis Ababa should be as per the WHO specification. This can be done by close cooperation of the government, NGOs, private sectors, and the community.
- Every health-care center should have small size syringe incinerators, as mentioned in the research, on the site of syringe waste generation.
- The city should have well-designed central treatment plant that incorporates incineration, autoclaving and chemical-disinfection. To make the central treatment plant effective each health care center should highly practice well organized waste management mainly proper waste segregation.

In general, the long-term onsite and offsite health-care waste management and treatment options are summarized in table 6.1 below.

Table 6.1 health-care waste management and treatment options

Waste Management Technology	Waste type	Recommended Options
Waste segregation and minimization	Sharps	➢ Should not be mixed with any kind of wastes ➢ Should be kept in safety boxes or incinerated at the generation point.
	Other wastes	➢ Color-coded waste bin segregation at point of generation should be practiced. ➢ Application of less waste generating materials
Storage	All type of wastes	➢ There should be primary storage area near by the generation sources mainly wards ➢ There should be well-designed, refrigerated, easily cleanable and controlled secondary storage area in each hospital.

Transportation	All type of wastes	➢ Three or four wheel trolleys, which have different compartments for different wastes and are easily cleanable, should be used. ➢ Off-site transportation vehicles, which fulfill the WHO specification, should be in practice.
Treatment	Sharps and hazardous wastes	➢ Off site controlled incineration, in multiple chamber incinerators.
	Recyclable wastes in need of special treatment.	➢ Recycling after steam sterilization or autoclaving near by the off-site incinerators applying the heat recovered from the incinerated waste and additionally chemical disinfection if needed.
	General wastes and incineration ashes	➢ Properly designed sanitary land fill which is compatible with environmental protection.
	Un-infected recyclable wastes	➢ Controlled recycling after separate autoclaving.

iv. Application of central treatment and heat recovery plant

As discussed earlier the heat generated from the solid waste incineration produces the energy less than medium capacity steam generators. Even though the energy generation is less for high-energy production it can be used for pre-heating of the incinerated waste to save the fuel consumption or can be used for steam generation for the treatment of recyclable materials. But for this purpose the feasibility study and design options should be thoroughly studied.

In addition, to get additional data about Addis Ababa solid health-care waste generation rate and composition, similar studies should be conducted in other health- care centers.

Finally implementing the above recommended health-care waste management options and mechanisms will improve the health, environmental and social impacts that arose from poor solid health care waste management, treatment and disposal.

References

Richard G. Bond, Conrad P. Straub (1975), Handbook of environmental control, volume II, solid waste

Federal Environmental protection Authority (FEPA)(2002), State of Environment report for Ethiopia, Addis Ababa, Ethiopia

Central Statistical Authority (ECSA) (1999), the 1994 population and Housing Census of Ethiopia. Results for Addis Ababa, Vol. I, Vol. II, Statistical report, Addis Ababa, Ethiopia.

Yetayal Beyene (2005), Domestic solid waste quantity and composition analysis in Arada sub-city, Addis Ababa University, Addis Ababa, Ethiopia, Unpublished MSc. Thesis

Worku Gebreselassie (2003), What can be done to the hospital waste of Addis Ababa to improve the sanitation of the hospital, Century university final Masters project

Taddesse Kuma (2003), Dry waste management in Addis Ababa city, Ethiopian Development Research Institute Teaching work shop on Accounting for Urban Environment, Addis Ababa, Ethiopia, Draft for discussion

Addis Ababa City Administration (AACA)(2003), Dry waste administration policy, Addis Ababa, Ethiopia

A. Pruss, E. Giroult, P. Rushbrook (1999), Safe management of wastes from health-care activities, World Health Organization (WHO), Geneva, Switzerland

Federal Democratic Republic of Ethiopia Ministry of Health (FMOH) (2005/06), Health and health related indicators, Addis Ababa, Ethiopia

Dr. Shamala.K, Ms. Shebuhangi Wankhede, Unique Endeavour of a partnership between an NGO, Government and end users towards biomedical waste management, CHAMP CBWTF, Gulbarga India

UNEP/SBC& WHO (2004), Preparation of national health-care waste management plans in sub-Saharan countries guidance manual, reviewed in Pretoria, South Africa

Khairun Nessa, M.A. Quaiyum, Barkat-e-Khuda (2001), Center for health and population research, Waste Management in Healthcare Facilities, ICCDDR,B Working paper No. 144, Dhaka, Bangladesh

Colorado department of public health and environment (CDPHE), revised January (2005), Solid infectious waste management, Colorado http://www.cdphe.state.co.us/hm / Accessed February, 2007

Lars M. Johannessen, Marleen Dijkman, Carl Bartone, David Hanrahan, M. Gabriela Boyer, Candace Chandra (2000), Health-care waste management guidance note, The World Bank, Washington DC, USA

Department of health of Manila (DHM) (2000), Health-care waste management manual, Manila, Philippines

Global south, Health care with out harm, http://www.noharm.org/globalsoutheng/electronics/issue , Accessed February, 2007

Benny Joseph (2005), Environmental studies, Mepco Schienk Engineering College, New Delhi

M.B Pescod & C.B. Saw, Urban waste expertise program (UWEP) (1998), Hospital waste management in four major cities, synthesis report, Netherlands

World Health Organization (WHO), Wastes from health-care activities, http://www.who.int/bulletin, Accessed May 2007

John Snow Inc./ Medical infections safer project & Federal ministry of health (FMOH) (2006), Health-care waste management national guide lines (Draft), Addis Ababa, Ethiopia

D. Joseph Hagerty, John E. Heer, Joseph Pavoni (1973), Solid Waste Management

Federal Democratic Republic of Ethiopia Ministry of Health (2005), Strategic plan of action proposal for the improvement of hospital infectious waste management system and hygiene practice, Addis Ababa, Ethiopia

FMOH EHD Industry and other institutions hygiene control team (FMOHEHD), (2004), Assessment of the status of hospital infectious waste management system and hygiene practice, analysis of results of survey conducted in four federal hospitals of the Ministry of Health, Addis Ababa, Ethiopia

Basel convention on the control of trans boundary movements of hazardous wastes and their disposal adopted by the plenipotentiaries, 1989

Federal democratic republic of Ethiopia (2002), Federal Negarit Gazeta, , 9th year No, 11, Addis Ababa, Ethiopia

Federal democratic republic of Ethiopia, 2002, Federal Negarit Gazeta, 9th year No, 12 , Addis Ababa, Ethiopia

Environmental Protection Authority & Ministry of Economic Development and Cooperation(EPA & MEDC) (1997), Environmental policy of Ethiopia, Addis Ababa, Ethiopia

WHO regional office for Europe & Center for Environmental Management and Planning (1992), Environmental and Health impact assessment of development projects, London & New York

Federal ministry of health (FMOH) (2005/2006), Health and health related Indicators, Addis Ababa, Ethiopia

Federal ministry of health (FMOH) (2004/2005), Health and health related Indicators, Addis Ababa, Ethiopia

Prem S. Mann, Introductory statistics (2nd edition) (1995), Eastern connecticus state university, New York, USA

Larry L. Anderson & David A. Tillman (1977), Fuels from waste, New york, USA

Robert H. Perry & Don green, 1984, Perry's chemical engineers hand book, sixth edition, Japan

Annex

Annex 1: United Nations packaging requirements for infectious substances, class 6.2, UN No. 3291:

CLINICAL WASTE, UNSPECIFIED, N.O.S., OR (BIO) MEDICAL WASTE, N.O.S., OR REGULATED MEDICAL WASTE, N.O.S. (adapted to hazardous health-care waste) [a]

There are two possibilities for packaging:

- Rigid and leak-proof packaging (complying with a number of requirements and tests specified by the United Nations (1997)).
- Intermediate bulk containers—large rigid or flexible bulk containers made from a variety of materials such as wood, plastics, or textile (complying with a number of requirements and tests specified by the United Nations (1997)).

Packaging or intermediate bulk containers intended to contain sharp objects such as broken glass and needles shall be resistant to puncture and shall undergo additional performance tests.

(Source: WHO 1999 Safe management of wastes from health-care activities)

Annex 2: Questioners

Questioner for skilled personnel

1- For waste storage and waste segregation:

1.1 Is it easy to segregate wastes at generation point in your health-care center recently? Yes_____ No_____

1.2 Does waste segregation at the generation point practiced? Yes_____ No_____

b- Is there any colour segregation for different kind of waste bins at generation point? Yes_____ No_____

If yes, please specify____

b- Is there any mixing of other wastes with sharps Yes_____ No_____

If yes, why? ____

c- Is there any international marking symbol for the containers of sharps and hazardous wastes? Yes_____ No_____

1.3 a- Does the temporary waste storage bins well designed, and easily cleanable? Yes_____ No_____

b- Does the temporary waste storage bins disposable? Yes_____ No_____

2- For waste collection and transportation:

a- Is there a scheduled programming of waste collection in your health-care centre? Yes_____ No_____

b- Is there any labelling on the waste disposal bins referring the generation point? Yes_____ No_____

c- Is there a continuous follow up of disposal schedule? Yes____ No_____

d- Is there well designed waste transportation mechanism in your health care facility? Yes_____ No_____

e- Does the workers have standardized safety wearing (duty glove, aprons, boots...) ? Yes_____ No_____

f- Does the waste containers appropriately sealed during disposal? Yes_____ No_____

g- Does the waste bins removed and replaced immediately when they are no more than three- quarters full? Yes_____ No_____

h- Is there well designed (Refrigerated, having internal rounded angled...) waste transportation vehicles for offsite solid waste disposal?

Yes_____ No_____

I- Does your health care centre use municipal waste disposal facilities?

Yes_____ No_____

3- For on-site health care waste storage:

a- Does the facility have dedicated and well designed place?

Yes_____ No_____

b- Are there any animals, insects having the access to the storage site?

Yes_____ No_____

c- Does the health care waste stays in the storage area for more than 24 hours with out disposal? Yes_____ No_____

4- For waste treatment and disposal:

4.1 -What kind of health care solid waste disposal system (treatment technology) does your health-care facility use recently?

a. Incineration Yes_____ No_____

If yes, of what type, Open burning Yes_____ No_____

Rotary kiln Yes_____ No_____

Pyrolitic incinerator Yes_____ No_____

Specify if other type___________________________________

b. Chemical disinfections Yes_____ No_____

c. Wet and dry thermal treatment Yes_____ No_____

d. Microwave irradiation Yes_____ No_____

e. Land disposal Yes_____ No_____

If yes, 1- Open dumps to municipal disposal site Yes___ No_____

2- Sanitary land fills Yes_____ No_____

Specify if other type___________________________________

f. Inertization Yes_____ No_____

5- For Impact determination:

5.1 - How do you rate the impacts of health care wastes disposal in your health-care centre? Remark: Put your judgement comparing one with the other

Type of Impact	Rating		
	3	2	1
Environmental impact			
Health impact			
Social impact			

5.2 - what are the Environmental impacts arose from the Solid health-care waste disposal in your health care center?

a. Micro climate hazards (for climate and air) Yes_____ No_____

b. Generation and dispersion contaminants (for climate and air) Yes_____ No_____

c. Soil contamination Yes_____ No_____

d. Ground or surface water contamination Yes_____ No_____

e. Odour Yes_____ No_____

f. Loss of clear site due to the smoke Yes_____ No_____

Is there another type of environmental impact arose? If yes, specify

____

5.3 - what are the Health impacts arose from the Solid health-care waste disposal in your health care center?

a. Infection through puncture, abrasion or cut in the skin (Leading risks to HIV, Viral hepatitis and other infections) Yes_____ No_____
b. Infection through inhalation and ingestion Yes_____ No_____

c. Exposure to toxic, genotoxic, corrosive, flammable, reactive or explosive chemicals or pharmaceuticals Yes_____ No_____
d. Exposure to radioactive wastes Yes_____ No_____

Is there another type of Health impact arose? If yes, specify

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5.4 - what are the Social impacts arose from the Solid health-care waste disposal in your health care center?

a. Noise from disposal facilities (eg: - Incinerators) Yes_____ No_____
b. Loss of aesthetic quality Yes_____ No_____
c. Loss of Job due to infection by the current solid waste disposal system failure (Specially on cleaners, hospital staffs...) Yes_____ No_____

Is there another type of social impact arose? If yes, specify____________________

5.5 - According to their probability of exposure to health-care waste disposal, please rate the following individuals risk probability in your health care facility

Remark: Give 5 for high probability and 1 for low probability.

Main group	Risk probability				
	5	4	3	2	1
Medical doctors, nurses (Medical staff)					
Patients in health care center or receiving home care					
Visitors to health care establishments					
Supportive staff in healthcare establishments					
Workers in disposal route (Janitors, Cleaners...)					
Scavengers at disposal sites					
Community around the health care center					

5.7- How do you judge the waste disposal system (action) in your healthcare center

Excellent_____ V.Good _____ Good _____ Satisfactory_____ Poor______

Why? ____

5.8- In your perception who are responsible for proper disposal system implementation in health care centres?

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a. Medical doctors, nurses (Medical staffs) Yes_____ No_____
b. Sanitarians, Environmentalists... Yes_____ No_____
c. Workers in disposal routes (Cleaners, Janitors...) Yes_____ No_____
d. Owners or management staffs of the health -care centres Yes_____ No_____
e. Community Yes_____ No_____

If there are other parties please specify____

5.9- Do you agree on the need of having well designed central health-care waste disposal/treatment plant for the city of Addis Ababa? Yes_____ No_____

Why? ____

5.10 - What kind of treatment plant do you recommend for the city of Addis Ababa, assuming most of the health care centres produce same type of wastes as your center? Why? ____

5.11- Is there any complaint that you heard that arose from the neighbouring community about the disposal of solid health-care wastes from your centre?

Yes_____ No_____

Why? ____

5.12- Is there any complaint that you heard that arose from the health-care centre workers about the disposal of solid health-care wastes from your centre?

Yes_____ No_____

Why?____

5.13- Please add any comment that was not mentioned on the questioner and you fell it is important?

Questioner for Janitors and cleaners

1 - Is there any solid waste segregation in your health-care center? Yes____ No____

2 - is there a scheduled programming of waste collection in your health- care center? Yes____ No____

3 - Is there any mixing of other wastes with sharps? Yes____ No____

4 - Does the facility have dedicated and well designed primary storage place? Yes____ No____

5 - Does your facility has waste treatment plant? Yes____ No____

6 - Are you married? Yes____ No____

7 - Do you have families that rely on your salary? Yes____ No____

8 -If your answer for question no 7 is yes, how many? Yes____ No____

9 -Have you been exposed to puncture from disposed sharps? Yes____ No____

10-Do you know a person exposed to puncture from disposed sharps? Yes___ No___

11- Does your health care center fulfil standardized safety wearing for cleaning staff (duty glove, aprons, boots...)? Yes____ No____

Do you have heavy-duty gloves? Yes____ No____

Do you have Apron? Yes____ No____

Do you have heavy-duty shoes? Yes____ No____

Do you have proper cleaning materials? Yes____ No____

Do you have nose and mouth protecting masks? Yes____ No____

12- Please specify your salary? ___________________

13- Does your health-care center cover your health cost? Yes____ No____

14- Does your health-care center cover health cost of your family? Yes____ No____

15- Have you noticed smoke during waste incineration? Yes____ No____

16- Where does the ash from incineration be disposed in your health-care center? Yes____ No____

17- Do you remember the time you were sick due to poor solid waste management? Yes____ No____

If there is, how many times? _________________

18-How many hours do you be at work per day? ________________

19-Do you work shift wise? Yes____ No____

20- If you work shift wise how many shifts do you work per day? Yes____ No____

Annex 2.1 Background of the study area

➢ St. Paulos Specialized General Hospital

The hospital is located 09002’48N, 038043’36E and at an elevation 2,519m in Addis Ababa, Gulele sub-city administration. It is one of the federal hospitals of the Ministry of health. It has a total of seven wards with 250 beds and it is a specialized general hospital.

➢ St. Petros Specialized Hospital

St. Petros hospital is located 09000’35N, 038043’25E and at an elevation 2,370m in Addis Ababa, Gulele sub-city administration. It is one of the federal hospitals of the Ministry of health. It has a total of five wards with 200 beds and specialized on management and treatment of patients with tuberculosis.

➢ Minilik II Specialized Hospital

Minilik II hospital is located 09^{0}02’16N, 038^{0}46’28E and at an elevation 2,501m in Addis Ababa, Yeka sub-city administration. It is under the regional health bureau. It has a total of 246 beds and specialized general hospital. It specialized on the treatment of bone and eye patients.

➢ Bethezata General Hospital

Bethezata general hospital is located 09^{0}00’42N, 038^{0}45’15E and at an elevation 2,342m in Addis Ababa, Kirkos sub-city. It is a private hospital. It has a total of 75 beds and it is a general hospital

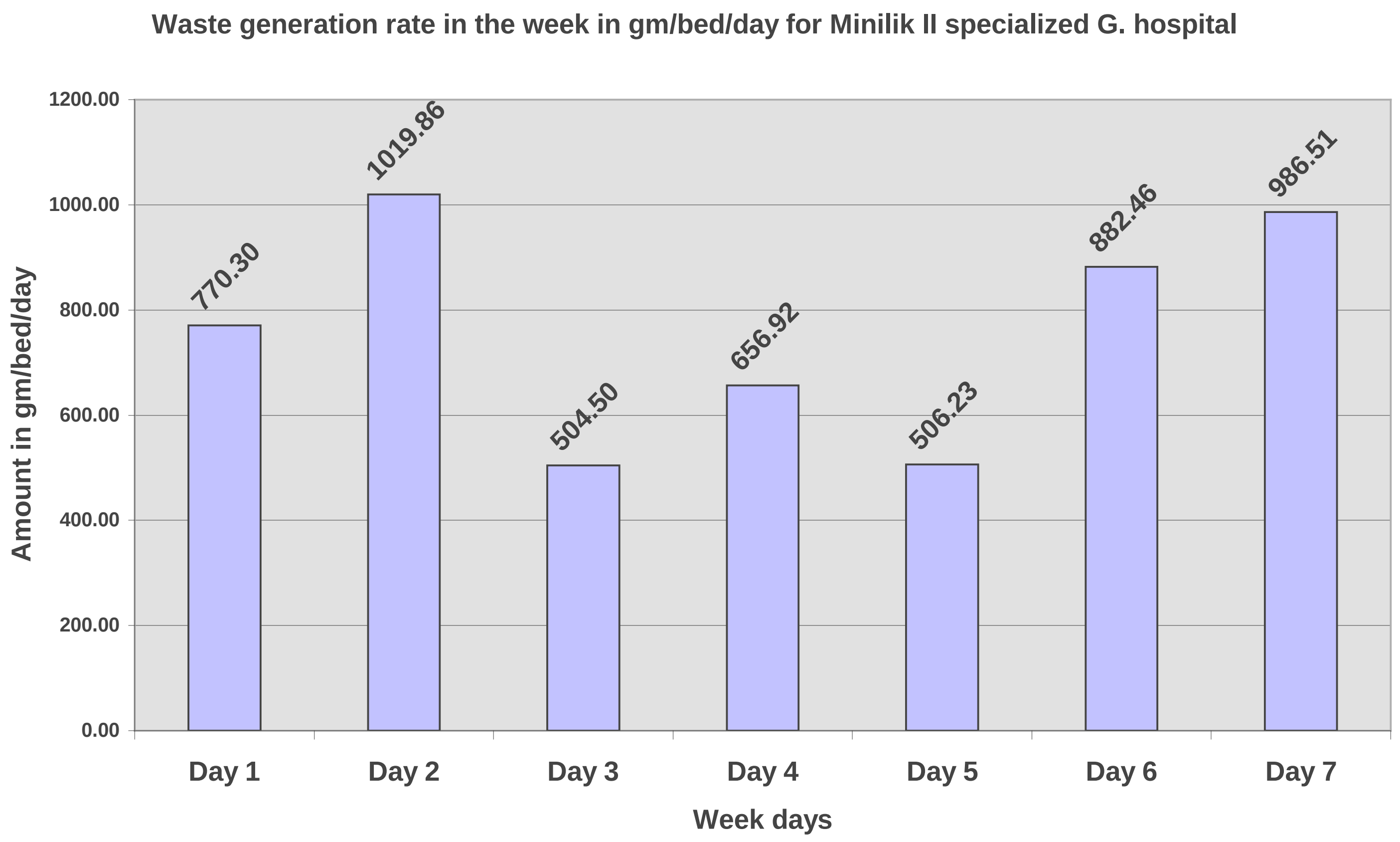
➢ Zenbaba General Hospital

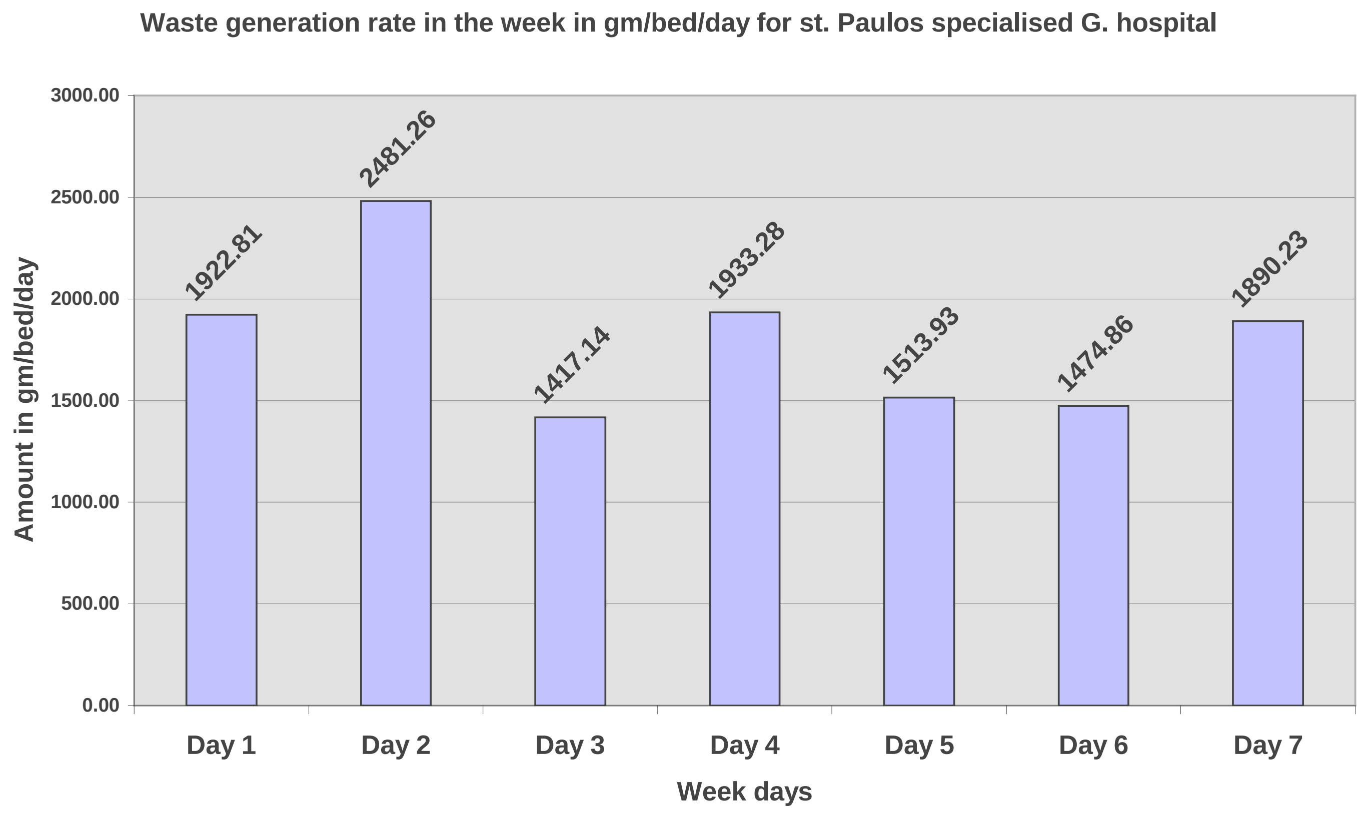
Zenbaba general hospital is located 08^{0} 57’15N, 038^{0}45’15E and at an elevation 2,269m in Addis Ababa, Nifas silk-lafto sub-city. It is a private hospital. It has a total of 27 beds and it is a general hospital.

Annex 3: Weekly waste data collection sheet

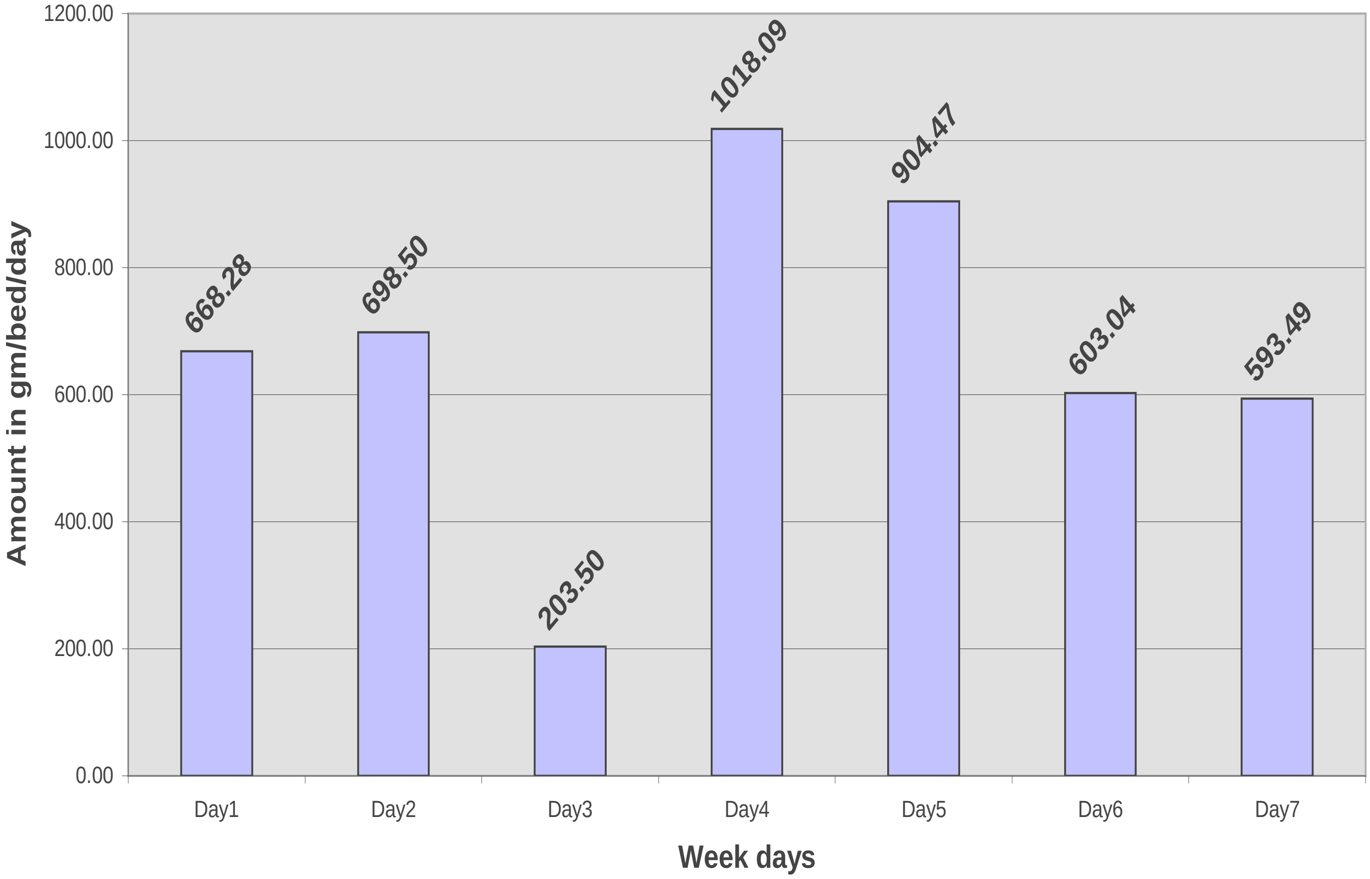
Hospital solid waste	Type of waste	Mon-day	Tues-day	Wednes-day	Thurs-day	Fri-day	Satur -day	Sun-day
Infectious waste	-Sharps - needles - glass infected by blood or body fluids							
	- Recyclables - glucose and other fluid holding plastics - Packing materials - Paper/ card boards etc							
	- Solid wastes from patient care duties - Bandages /goose - glove							
	- Anatomical parts (if any)							
Non infectious waste	- Food debris - Food leftovers - Fruit leftovers - Packed food leftovers							
	- General wastes - Dust - Paper and office wastes							
	- Recyclable materials - Glass , X-ray plastics - uninfected plastics used for packaging etc - Metals excluding sharps having direct contact with body fluids							

Annex 4: Mean HCW generation rate in each day for sample hospitals in Kg/bed/day

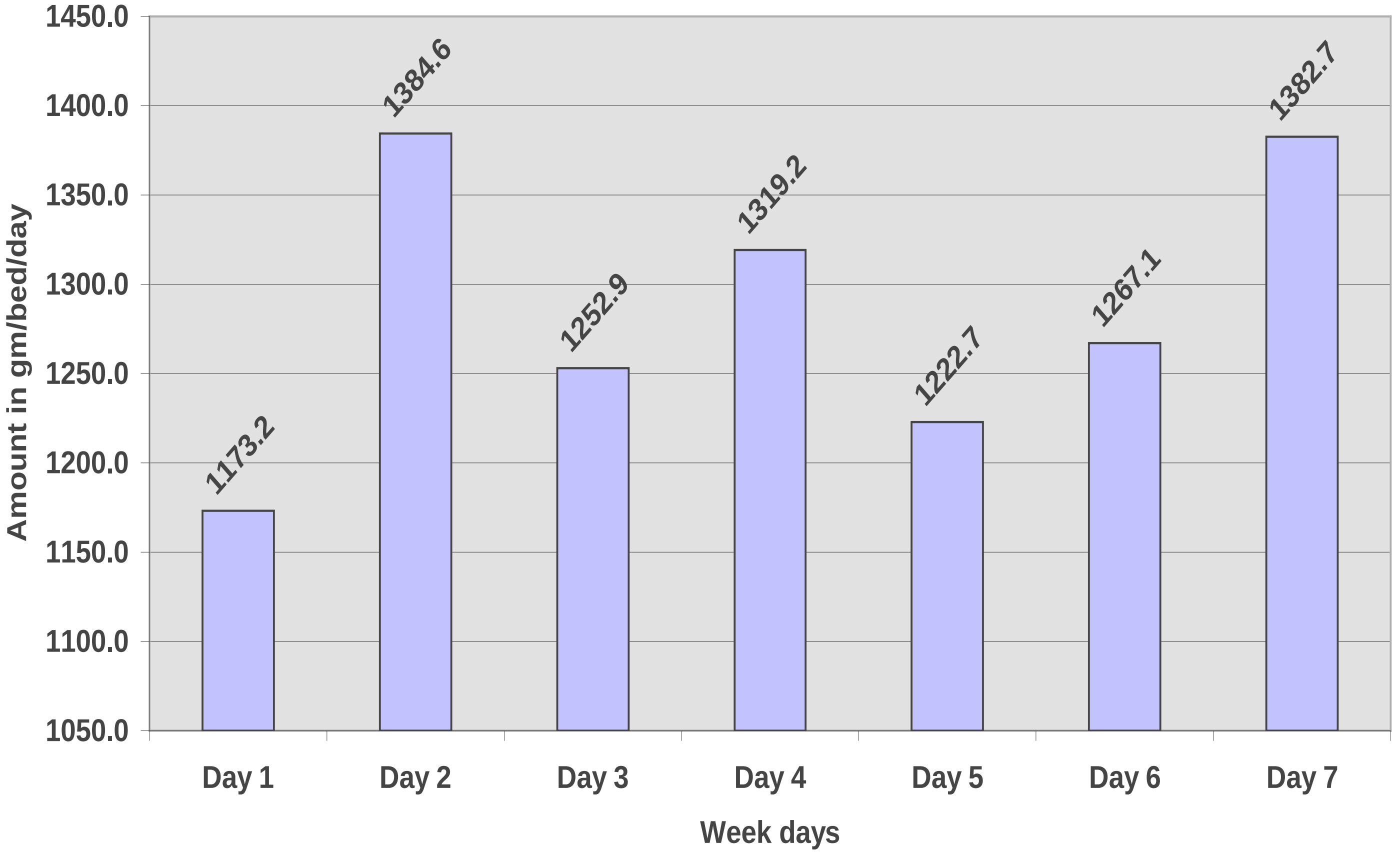




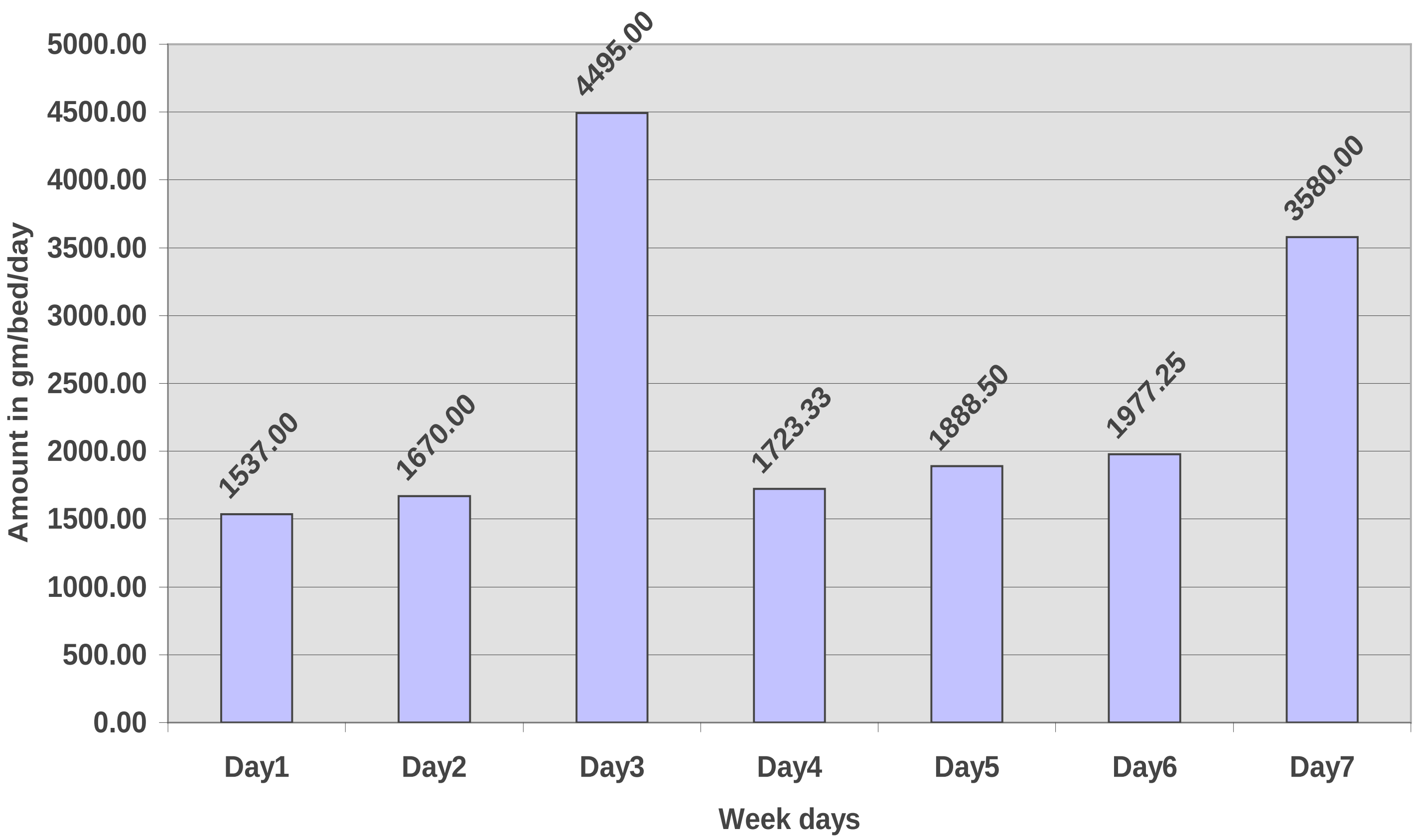
Waste generation rate in gm/bed/day in week days for st.peter specialised hospital



Waste generation rate in gm/bed/day in week days for Bethzata G. hospital



Waste generation in gm/bed/day in week days for Zenbaba general Hospital



Annex 5: Mean solid HCW generation rate for all Governmental and private hospitals

Governmental Hospitals					
Health-care centre	Number of sample beds taken (Sample size) =n	Total occupied beds (population size) in the week =N	Sampling distribution for all sample Governmental hospitals	(Mean)X (Sample distribution)	(Mean^2)X Sample distribution
Minilik II specialized hospital	21	148	0.28	215.95	164331.70
St. Poulos specialized G. hospital	29	240	0.39	707.28	1276493.86
St.Peter specialized G. hospital	24	80	0.32	217.27	145550.32
Bethzata General hospital					
Zenbaba General hospital					
Total	74	468	1.00		1586375.89
Mean of waste generation for sample hospitals					1140.50
Standard deviation of sample					534.45
Interval for mean = ±					534.45
Mean value Kg/day/bed=					1.141±0.535
Estimated bed occupation rate in %					61.25
Total estimated Bed Occupation in the city					835

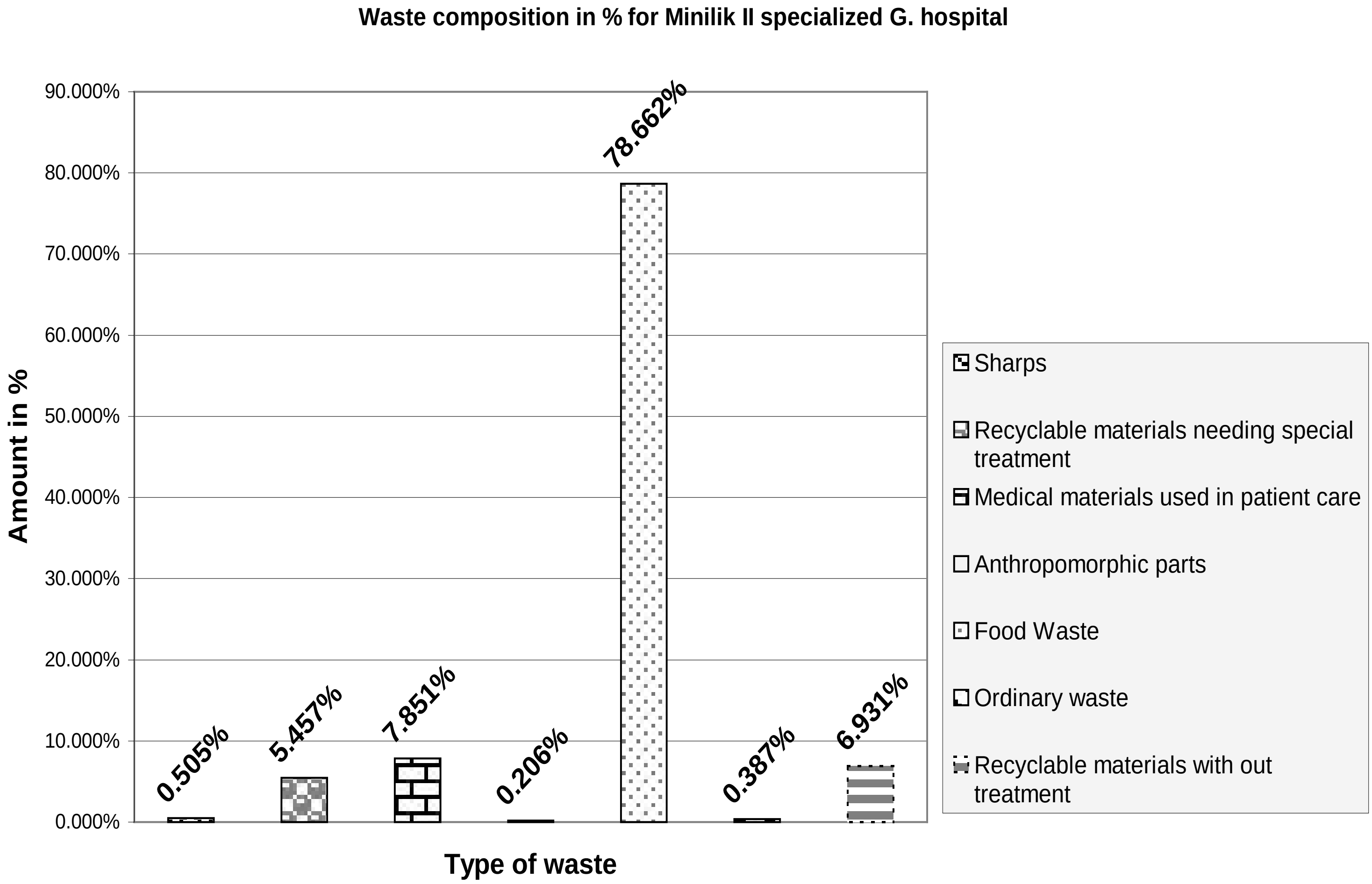
Private, OGO and NGO hospitals					
Health-care centre	Number of sample beds taken (Sample size)=n	Total occupied beds (population size) in the week=N	Sampling distribution for all sample hospitals	(Mean)X (Sample distribution)	(Mean^2)X Sample distribution
Minilik II specialized hospital					
St. Poulos specialized G. hospital					
St.Peter specialized G. hospital					
Bethzata General hospital	6	33	0.60	771.63	992365.08
Zenbaba General hospital	4	4	0.40	964.06	2323538.39
Total	10	37	1.00		3315903.47
Mean of waste generation for sample hospitals					1735.70
Standard deviation of sample					550.69
Interval for mean = ±					1.009
Mean value Kg/day/bed=					1.735 ±1.009
Estimated bed occupation rate in %					38.75
Total estimated Bed Occupation in the city					528

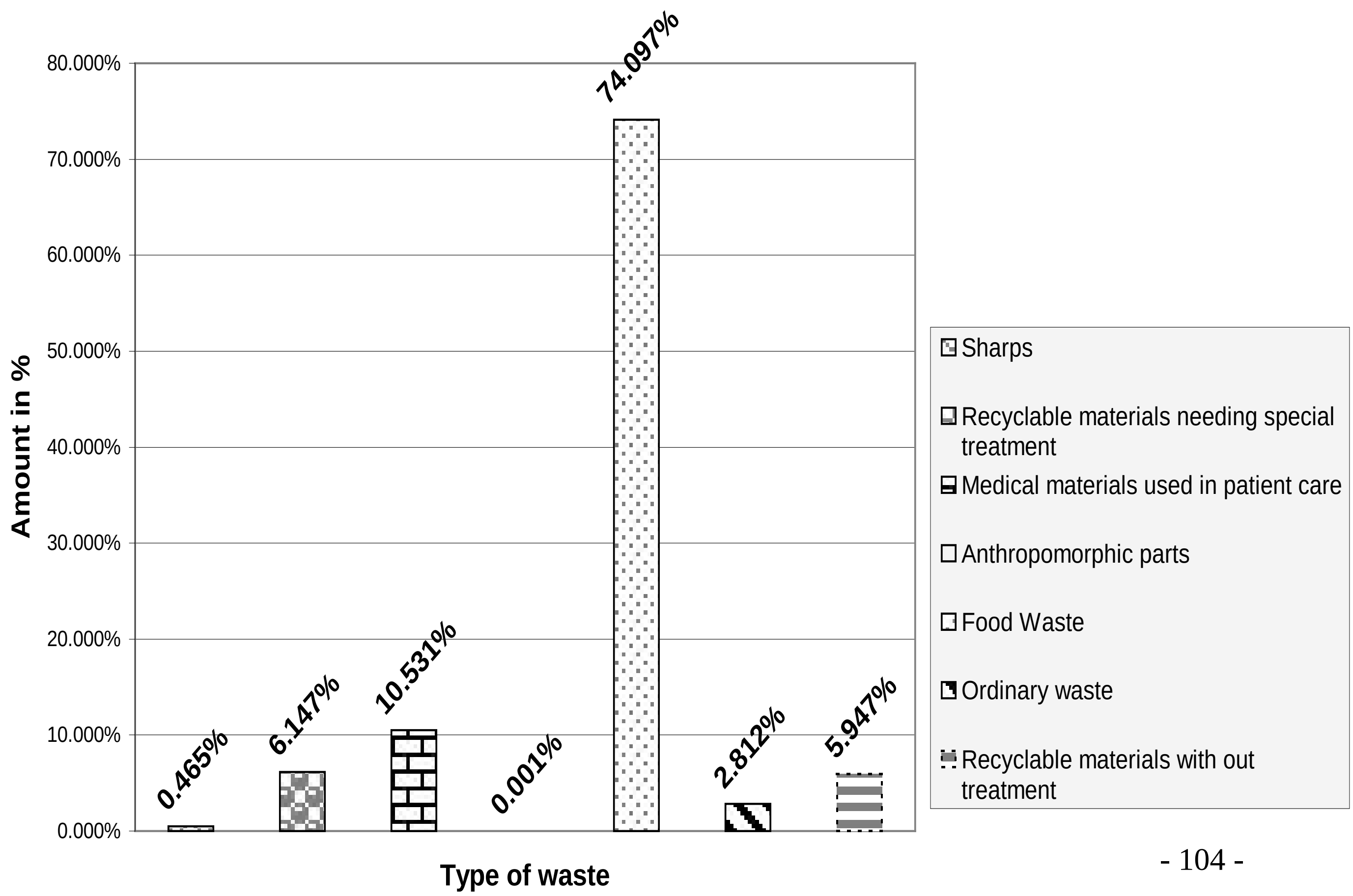
Annex 6: Data used to predict expected bed occupancy rate for the year 2006-2007

Year	Population	Bed occupancy rate in %	Total expected no of beds in the city	Governmental	Private, OGO, NGO
2004-2005	2887615	32.6	4449		
2005-2006	2973000	32.3	4367		
2006-2007	3061000		4258	2608	1650

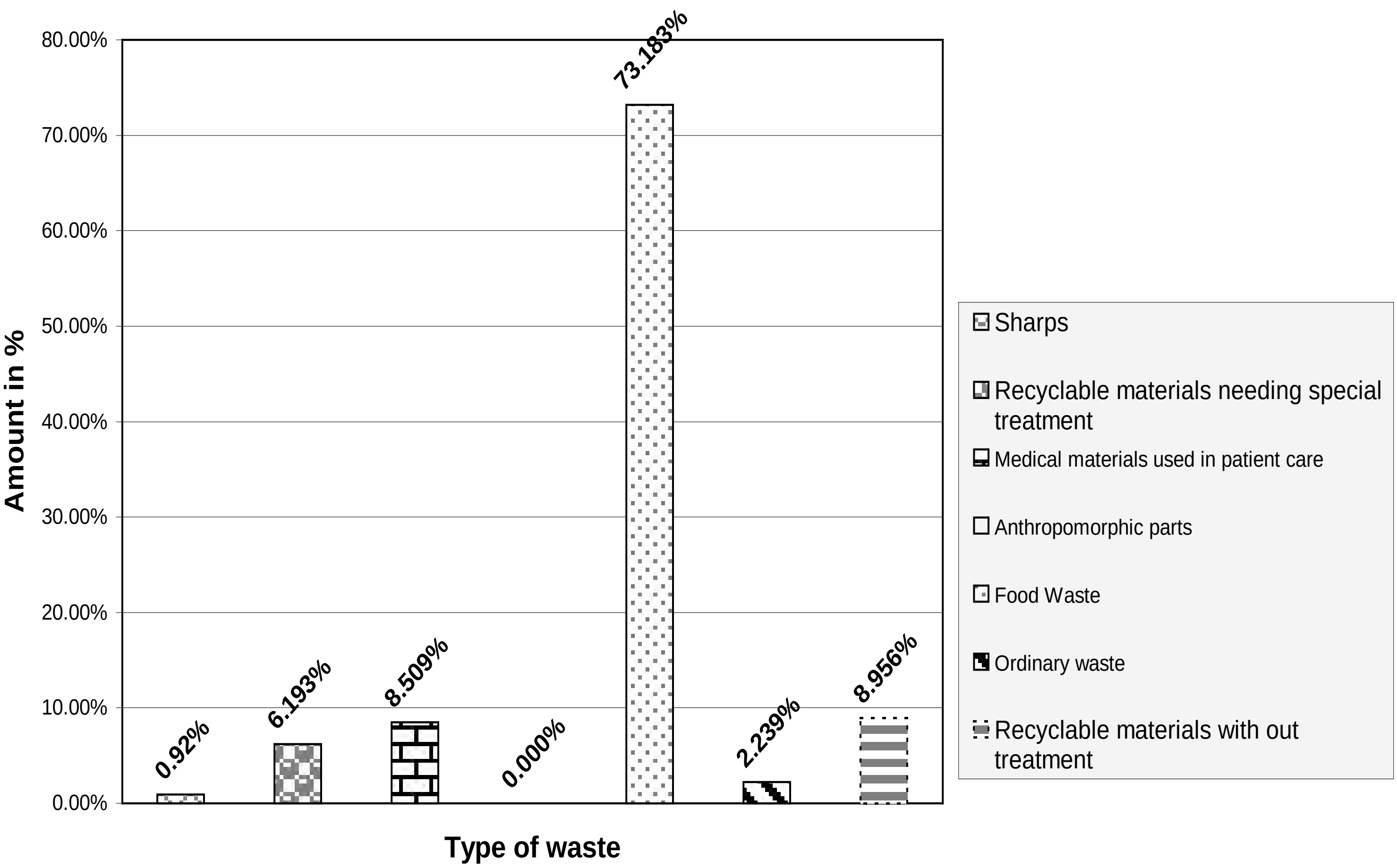
Remark: For 2006-2007 the value is expected amount from the increment of two private hospitals

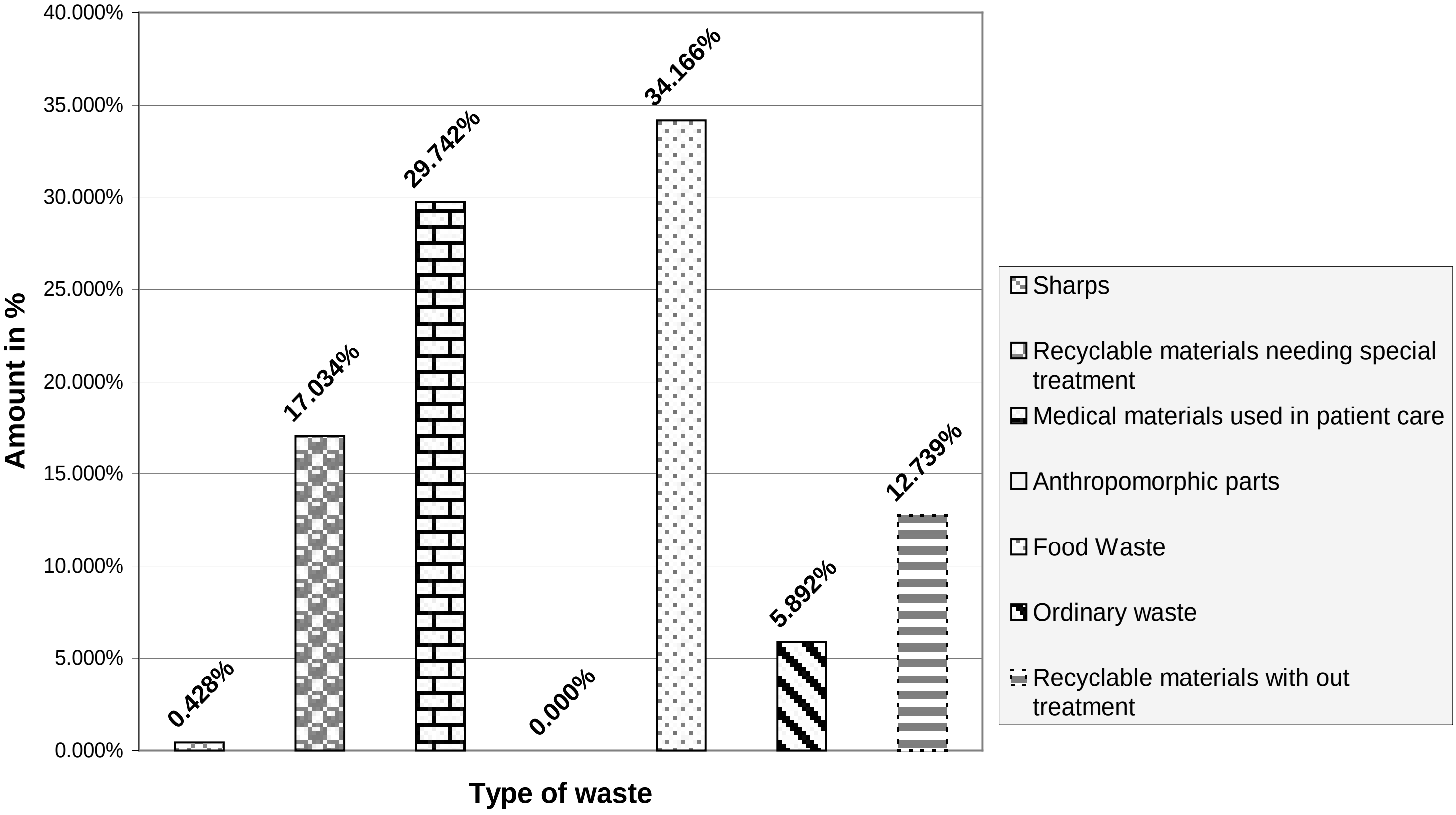
Annex 7: Graphical presentation for waste compositions in percent for sample hospitals

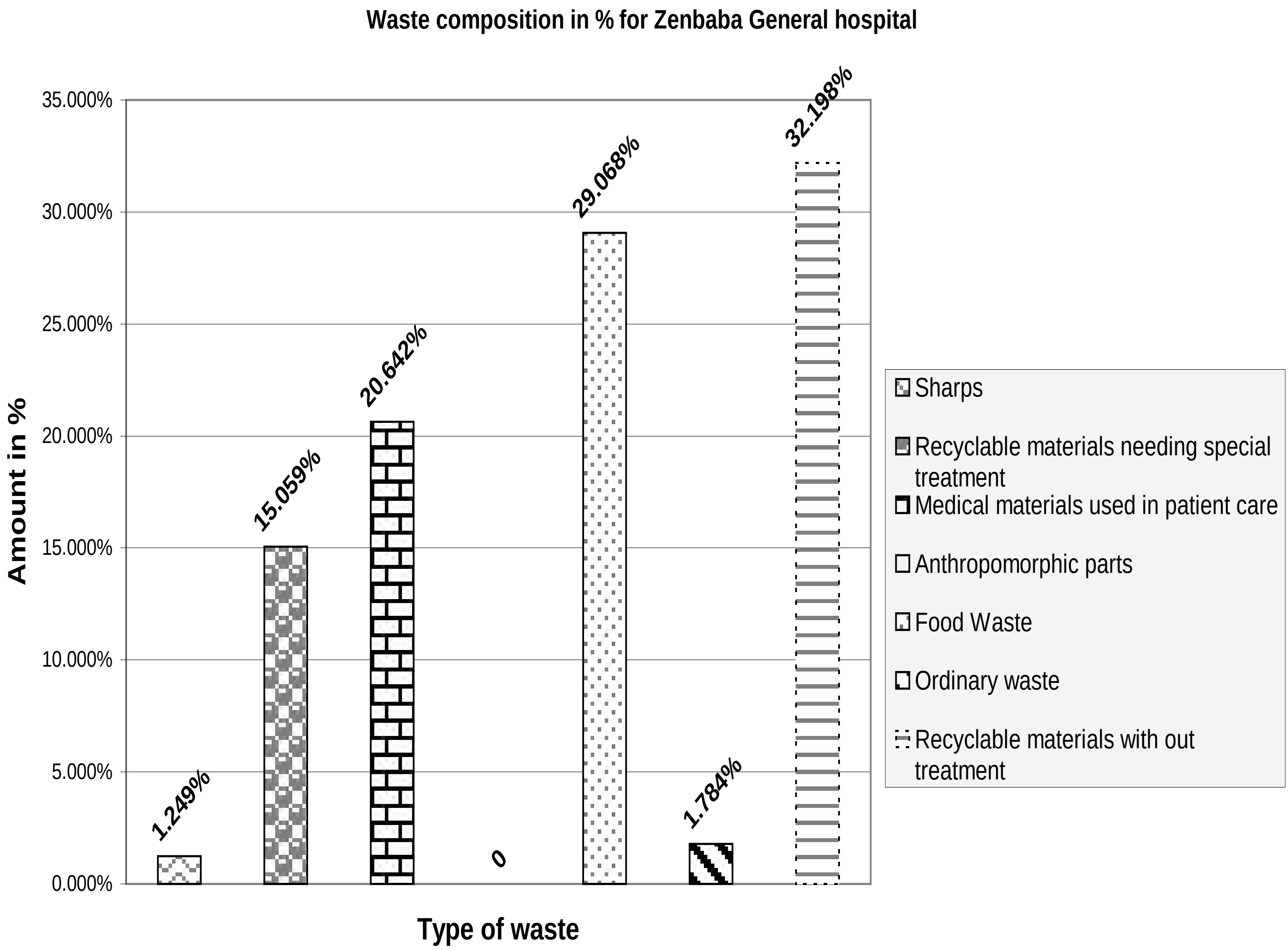




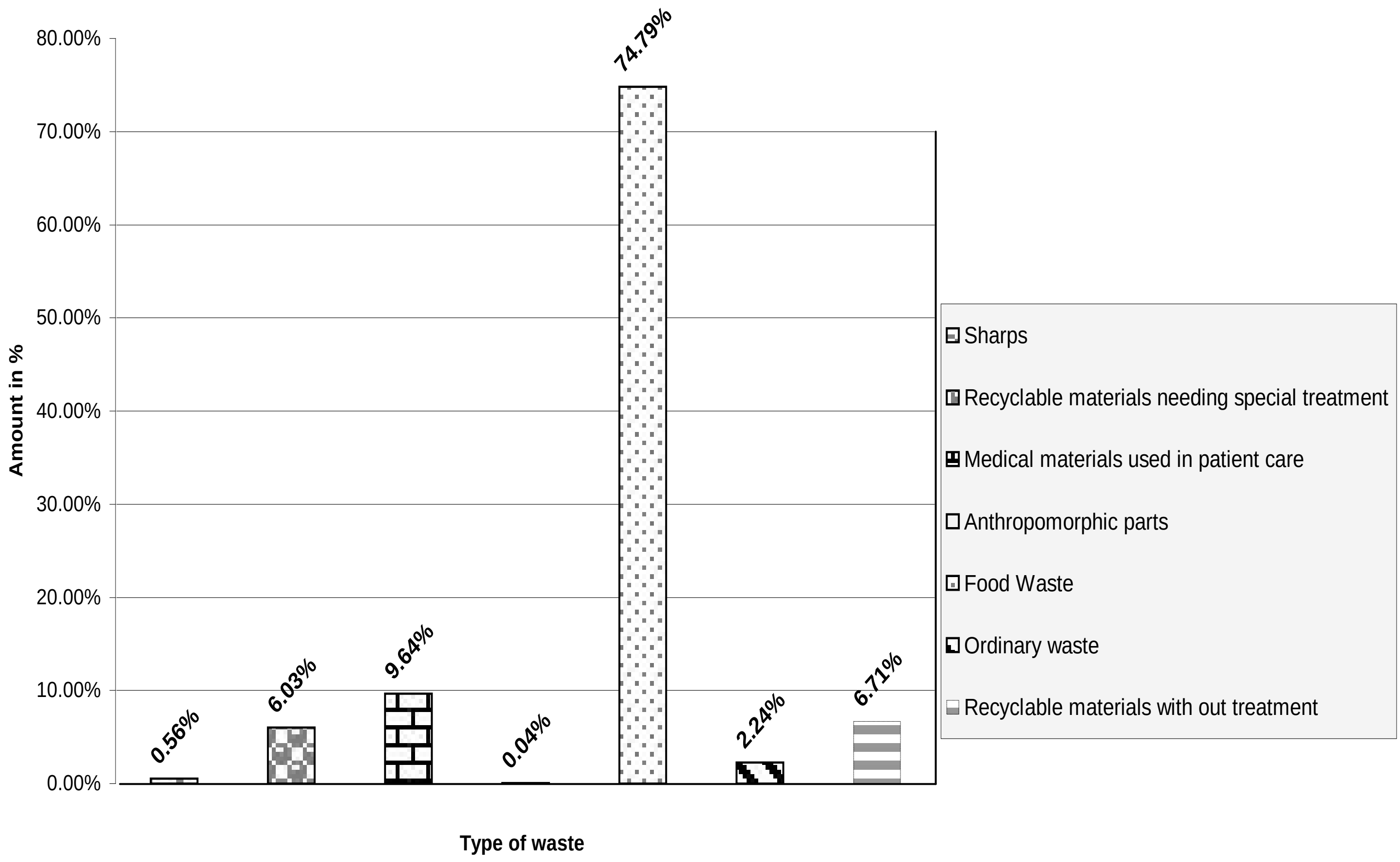
Waste composition in % for St. Peter specialised hospital

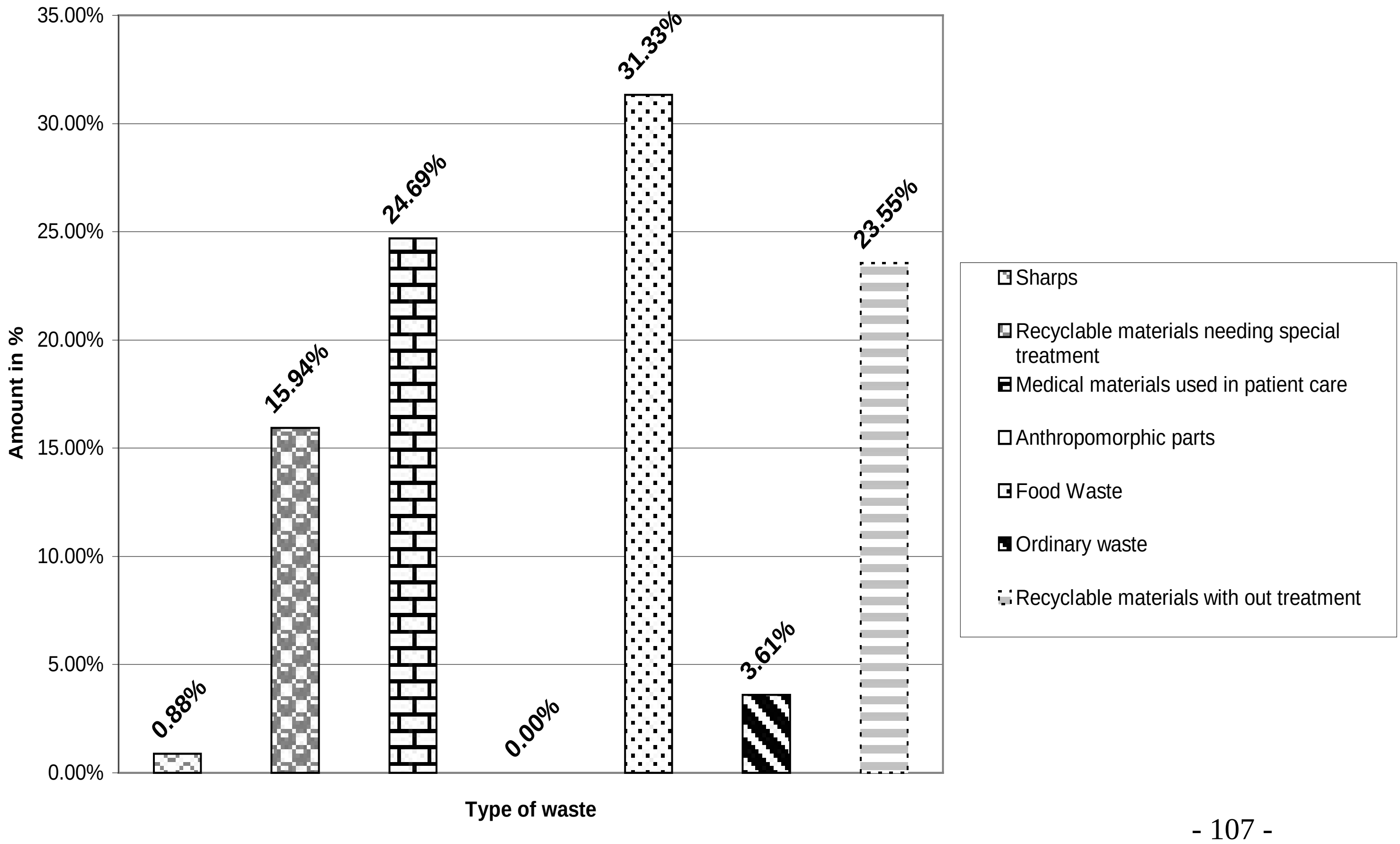





Waste composition in % for Zenbaba General hospital
35.000%
30.000%
25.000%
20.000%
15.000%
10.000%
5.000%
0.000%
Amount in %
1.249%
15.059%
20.642%
0
29.068%
1.784%
32.198%
Type of waste
Sharps
Recyclable materials needing special treatment
Medical materials used in patient care
Anthropomorphic parts
Food Waste
Ordinary waste
Recyclable materials with out treatment

Annex 8: Graphical presentation for waste compositions in percent for Specialized and general hospitals





Annex 9: Estimated probability of exposure in %

Exposed Group	Estimated exposure probability in %
a- Medical doctors, Nurses (Medical staff)	16%
b- Patients in health-care centre or receiving home care	10%
c- Visitors to health-care establishments	8%
d- Supportive staff in health-care establishments	15%
e- Workers in disposal route (Janitors, Cleaners…)	23%
f- Scavengers at disposal sites	17%
g- Community around the health-care centre	11%
Total	100%

Plates

Plate 1:

Waste segregation during sampling time

Plate 2:

(a)

(b)

(c)

Recyclable safety box (a), Disposable safety box full of sharps above 3/4th of the box (b), improper placement of safety boxes in one of the visited hospitals (c)

Plate 3:

(a)

(b)

(c)

Waste bins without proper covering and poor design for health care wastes (a) and (b), well designed reusable solid health-care waste disposal bins observed only in one of the hospitals visited (c)

Plate 4:

(a)

(b)

Poorly designed brick incinerator in one of the private hospitals visited (a), brick incinerator with poor design and placement in one of the visited governmental hospitals.

Plate 5:

(a)

(b)

(c)

Scattered solid health-care waste and ash from brick health-care waste incineration plants disposed near by incineration plants

Declaration

This thesis is my original work, and it has not been presented for a degree in any another university. The source materials used for the thesis are duly acknowledged.

Tatek Temesgen ___________________

Signature

This thesis has been submitted for examination with our approval as a university advisor

Dr. Nebyeleul Gessesse ___________________

Signature