Cape Peninsula
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MEDICAL WASTE MANAGEMENT AT TYGERBERG HOSPITAL IN THE WESTERN CAPE, SOUTH AFRICA

by

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DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not previously submitted it at any university in its entirety or in part for a degree.

.... June, 2007.

Signed **Date**

ABSTRACT

This study examined the medical waste management practices of Tygerberg Hospital. The researcher made use of both primary and secondary data. Since this was a is study, the analysis is essentially descriptive.

The results of this study revealed that both general and medical wastes are generated in the hospital. Tygerberg Hospital does not quantify medical waste. Segregation of medical wastes into infectious medical waste and non-infectious medical waste is not conducted according to definite rules and standards. The hospital does not label infectious waste with Biohazard symbol. Separation of medical waste and municipal waste is however practiced to a satisfactory extent. Wheeled trolleys are used for on-site transportation of waste from the points of production (different wards) to the temporary storage area. Staff responsible for collecting medical waste use almost complete personal protective equipment. The results of this study indicated that off-site transportation of the hospital waste is undertaken by a private waste management company. Waste is transported daily and small pickups are mainly used by the waste management company for transporting the waste to an off-site area for treatment and disposal. The final disposal of the medical waste is done by the private waste management company. The main treatment method used in the final disposal of infectious waste is incineration. Non-infectious waste is disposed of using land disposal method. The hospital does not recycle medical waste materials except white office paper and mixed office paper and the use of empty containers of antiseptics for the collection and temporary storage of sharps.

The hospital does not provide training for staff members on the health and environmental effects of infectious waste. The waste management company's workers have also not received any formal training with regards to medical waste management. The study showed that Tygerberg Hospital does not have a policy and plan in place for managing medical waste. There is no definite policy or plan for purchasing the necessary equipment and for providing the facilities for the correct management of medical waste in the hospital. There are also no policies and guidelines regarding the recycling of medical waste products. There are a number of problems the hospital faces in terms of medical waste management, including; lack of necessary rules, regulations and instructions on the different aspects of collection and disposal of waste, intermingling of hazardous wastes with domestic waste in the hospital sometimes, failure to quantify the waste generated in reliable records, lack of use of coloured bags by limiting the bags to only one colour for all waste, the absence of a dedicated waste manager, the supervisor in charge of general services has waste management as part of his job schedule, and there is no committee responsible for monitoring the management of medical waste. From the results of this study, it is obvious that medical waste management is not practiced according to the World Health Organisation's (WHO's) recommended standards. There are some areas where medical wastes are not properly managed. It is imperative for significant investment in the proper management of medical waste in order to reduce the health risk it poses.

DEDICATION

With gratitude to God, I dedicate this work to my dear Joshy and my lovely children, Ivana and Bastien.

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I first of all thank the Almighty God for the strength and wisdom to complete this work. May His Name be glorified forever! I am very grateful to my spouse and daughter for their understanding, sacrifice and support throughout my study. I really appreciate the time you spent and enormous contributions during my programme. I specially thank my supervisor, Mr. Anton Bouwer for the supervision and direction he gave me during this study. I am also grateful to Dr. James Odendaal for his comments and suggestions during the study. God bless you sirs. My acknowledgement goes to the management and staff of Tygerberg Hospital, especially the Deputy Director of Admistration and staff of the general services department and infection control unit for providing me with the necessary information for this research. I am grateful to Rev. Cornelius Yakung for proof reading my thesis. I also say a big thank you for all the support I received from Mr. Charles Adjasi during my study in South Africa. Also, to you all who helped in diverse ways and whom I have not specifically mentioned here, I say thank you. May the good Lord richly bless you!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Hospitals are health institutions providing patient care services. It is the duty of hospital and healthcare centres to take care of public health. This may directly be through patient care or indirectly by ensuring a clean, healthy environment for their employees and the community (Patil and Pokhrel, 2005). In the process of healthcare delivery, waste is generated which includes sharps, human tissues or body parts and other infectious materials (Baveja, Muralidhar, and Aggarwal, 2000) also referred to as "Medical Waste" or "Hospital Solid Waste". Medical wastes are defined to include all types of wastes produced by health facilities such as general hospitals, medical centres and dispensaries. Medical wastes represent a small amount of total residues generated in a community. However, such residues can potentially transmit diseases and present an additional risk to the staff of the healthcare facilities, patients and the community when the wastes are not managed properly (Silva, Hoppe, Ravanello and Mello, 2005). Improper disposal of medical waste including open dumping and uncontrolled burning for instance increases the risk of spreading infections and of exposure to toxic emissions from incomplete combustion.

Medical waste may be classified into different types according to the source, type and risk factors associated with their handling, storage and ultimate disposal. The European Union has been making a special effort to standardise waste classification through the establishment of the Waste European Catalogue (Alvim-Ferraz and Afonso, 2005). Meanwhile, many different classifications still are being considered in legislation and in the literature (WHO, 1992; Walker and Cooper, 1992; Wong, Narasimham, Kasyap, Fu, 1994; Blackmann, 1995; EEA, 1999; Liberti, Constantino, Ferrara, Nuzzo, 1996).

Throughout the world, the health sector is one area that has witnessed significant improvement. However, it seems that the fraction of waste generated at healthcare institutions has not attracted the same level of attention as other types of wastes, particularly in developing countries, despite the fact that medical waste is labeled as hazardous waste because it poses serious and direct threat to human health (Coad, 1992, WHO, 1999; Oweis, Mohamad and Ohood, 2005).

The public health impacts of medical waste are determined by the overall waste management strategy adopted by the hospitals or health centres. Medical or Hospital Waste Management involves management of a range of activities, which are mainly engineering functions, such as collection, transportation, operation/treatment of processing systems, and disposal of waste. However, in most cases, initial segregation and storage activities are the direct responsibility of nursing personnel. If the infectious component gets mixed with the general non-infectious waste, the entire mass becomes potentially infectious. It is the responsibility of hospitals and other healthcare institutions to ensure that there are no adverse health and environmental consequences as a result of their waste handling, treatment and disposal activities (Patil and Pokhrel, 2005). This present study focuses on the medical waste management practices of a major hospital in South Africa, Tygerberg Hospital, Western Cape.

1.2 Statement of Research Problem

Waste management has become a critical issue as it poses potential health risks and damage to the environment. It is an issue that is taking central place in the national health policies of many countries. In developing countries, solid wastes have not received sufficient attention. This is because, very often, health issues compete with other sectors of the economy for the very limited resources available. Thus, management of medical waste end up not getting the priority it deserves.

In many countries, hazardous and medical wastes are still handled and disposed together with domestic wastes, posing a great health risk to municipal workers, the public and the environment. Medical waste must be separated from municipal waste, but in many parts of Africa it tends to be collected along with the rest of the waste stream (Kgathi and Bolanee, 2001; Taru and Kuvarega, 2005). Most hazardous and toxic wastes are placed on landfills with few safeguards to protect nearby inhabitants and water sources from contamination. This is usually the case in developing nations (Hardoy, 1992).

In South Africa, for instance, medical waste is seen as a mounting problem. In recent times, there have been numerous press statements about medical waste being disposed of in an incorrect manner. This situation has adversely affected the poor disadvantaged members of society. The incineration of medical waste has also caused much concern. Some studies (Groundwork, 2002), have pointed out that incinerators have been associated with a wide variety of health problems in South Africa, such as disrupting the bodies hormonal, immune and reproductive systems, and even caused cancers. It is estimated that about 45% of healthcare waste generated in the Province of KwaZulu-Natal alone, for instance, cannot be accounted for, indicating that it is being illegally dumped, buried or burnt in unknown locations, thus affecting the health of the people and the environment (Leonard, 2004). The disposal of medical waste constitutes a problem in other parts of the country. Recently, the Cape Town Municipality gave a medical waste disposal company 24 hours to remove amputated body parts and foetuses that had been piling up outside its warehouse for some time (Barbeau, 2005).

South Africa is said to lack the capacity to properly dispose of the huge amounts of medical waste being generated. There have been numerous instances where medical wastes have been dumped in residential areas. The illegal dumping of medical wastes in disadvantaged residential areas has resulted in situations where children have been found playing with medical waste materials such as syringes. For example, the Tygerberg Hospital treated 48 children with AZT after some were pricked with needles and others ate potentially lethal pills they found in a field in Elsie's River (Leonard, 2004). Waste from medical facilities poses a risk to healthcare workers, patients and the local communities in South Africa.

In the light of all the above, this study aims at examining the medical waste management practices in the country. This current study empirically examines the medical waste management practices of Tygerberg Hospital in South Africa. Tygerberg Hospital is chosen because it is one of the leading hospitals in the country and in the Western Cape Province.

1.3 Research Questions

In order to achieve the objectives of this study, a number of research questions are put forward. Following from the discussion above, the following research questions are formulated:

1) How does Tygerberg Hospital manage medical waste?
2) What are the existing procedures involved in managing medical waste at the hospital?
3) Are there documented regulations and policies with respect to the management of medical waste at the hospital?
4) Are there acts of mismanagement with regards to medical waste management at the hospital?
5) What are the problems involved in managing medical waste at the hospital?

1.4 Objectives of the Study

The main objective of this study is to examine the medical waste management practices of Tygerberg Hospital. The specific objectives are to:

1) Report on the current status of regulations and procedures regarding medical waste practices at the Tygerberg Hospital.
2) Indicate mismanagement practices at the Tygerberg Hospital.
3) Investigate what problems the hospital encounters in managing medical wastes.
4) Make relevant recommendations aimed at improving the waste management system in the Tygerberg Hospital in particular and hospitals in general in South Africa.

1.5 Delineation of the Study

This research is a case study and focuses on the Tygerbeg Hospital in the Western Cape Province of South Africa. This study examines the medical waste management practices with particular reference to the Tygerberg Hospital.

1.6 Significance of the Study

The significance of this study are:

- It creates public awareness regarding the health risk of the medical waste.

- The study provides relevant recommendations to hospitals and medical centres on possible ways of managing medical waste disposal.
- The document also contributes to the already existing body of academic knowledge. In that, it serves as a source of information for subsequent research in this area.

1.7 Expected Outcomes, Results and Contribution of the Research

The findings of this study have important policy implications for policy-makers, hospital administrators and health personnel. Recommendations from the study will help stakeholders to address the current medical waste management problems in the country. The study provides directions regarding new and current technologies in medical waste management.

1.8 Organisation of the Study

The study is organised under five chapters: Chapter one is the introduction: it includes the background, the statement of problem, the objectives of the study, the significance of the study, scope and the limitations of the study.

In chapter two, related literature available on medical waste management is reviewed.

Chapter three deals with the methodology used in achieving the objectives of the study.

Chapter four covers the analyses and discussion of the results of the study.

In chapter five, the findings emerging from the analysis are summarised. Conclusions of the study are based on the findings and valid suggestions and recommendations in line with the objectives of the research are made.

1.9 Clarification of Basic Terms and Concepts

- **Medical waste** is waste generated from health institutions. This includes both infectious waste and non-infectious waste materials. Medical waste is also referred to as healthcare waste, hospital waste or clinical waste (Soncuya, Matias and Lapid, 1997; WHO, 1999; WHO, 2005).

- **Health institution or healthcare facility** includes hospitals, medical or research laboratories, clinics, offices of physicians and dentists, veterinarians, long term-care facilities (Soncuya *et al*, 1997; WHO, 1999).

- **Infectious waste** includes infectious materials that can cause disease to humans (WHO, 2005). Infectious waste means healthcare risk waste which is suspected to contain pathogens and which normally causes, or significantly contributes to the cause of increased morbidity or mortality of human beings, and includes but is not limited to sharps waste and anatomical waste; but excludes baby-nappies and sanitary pads (Godfrey, 2003).

- **Hazardous waste** means waste that may, by circumstances of use, quantity, concentration or inherent physical, chemical or infectious characteristics, cause ill health or increase mortality in humans, fauna and flora, or adversely affect the environment when improperly treated, stored, transported or disposed of (Godfrey, 2003)

- **Medical waste management** or healthcare waste management is a process that helps ensure proper hygiene in the health institution and safety of healthcare workers and communities (Sanitation Connection, 2002).

- **Waste disposal** refers to the final placement of treated waste (Johannessen, Dijkman, Bartone, Hanrahan, Boyer and Chandra, 2000; WHO, 2005).

- **Treatment of wastes** is mainly reducing direct exposure of waste to become less dangerous to humans, at recovering recyclable materials, and at protecting the environment (Johannessen *et al*, 2000).

- **Waste minimisation** is the prevention of waste production and/or its reduction (WHO, 2005).

CHAPTER TWO

LITERATURE REVIEW

This chapter provides an overview of the conceptual issues on medical waste management. It also reviews existing empirical literature on the subject matter.

2.1 Medical Waste Defined

Medical or healthcare wastes are in the form of solid and liquid wastes generated in the diagnosis, treatment or immunisation of human beings or animals; in medical research; or in production of vaccines or other substances produced from living organisms. They are commonly generated by hospitals, medical or research laboratories, clinics, offices of physicians and dentists, veterinarians, long term-care facilities (for example, nursing homes) and funeral homes. These wastes are simple to identify, to separate, and to treat properly. Hospital wastes include sharps (for example hypodermic syringes, glass slide, needles, razor and scalpels), human or animal tissue or excretion, medical products (including swabs and dressings) (Soncuya *et al*, 1997).

In developing countries, medical waste is typically derived from two main sources: emergency relief donations (i.e. leftover from international donor response to either a humanitarian crisis or a natural disaster) and long-term healthcare services. The aim of healthcare services is to reduce health problems as well as prevent potential risk. As a result waste, which is potentially harmful to public health and the environment, are often generated. Leftover emergency relief donations normally create a one off medical care waste issue, and can be dealt with in the same manner as long-term healthcare services waste (Johannessen *et al*, 2000).

The World Health Organisation defines medical or healthcare waste as the total waste stream from healthcare establishments, research facilities, laboratories, and emergency relief donations. In addition, it includes the waste originating from "minor" or "scattered" sources - such as that produced in the course of healthcare undertaken in the home (dialysis, insulin injections, etc.) (WHO, 1999).

2.1.1 Classification of Medical Waste

The World Health Organisation classifies medical or healthcare waste into communal waste or general waste and special waste. Communal or general waste is all solid waste not including infectious, chemical, or radioactive waste. This waste stream can include items such as packaging materials, bedding, waste water from laundries, office supplies and other substances that do not pose a special handling problem or hazard to human health or the environment (WHO, 1999).

Special waste consists of several different subcategories:

- Infectious waste contains pathogens (bacteria, viruses, parasites, or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts. This category includes cultures and stock of infectious agents from laboratory work, waste from surgery and autopsies on patients with infectious diseases, waste from infected patients in isolation wards, waste that has been in contact with infected patients undergoing hemodialysis (e.g. dialysis equipment such as tubing and filters, disposable towels, gowns and aprons, gloves and laboratory coats) and waste that has been in contact with animals inoculated with an infectious agent or suffering from an infectious disease (WHO, 1999).

- Pathological wastes consist of tissues, organs, body parts, human fetuses and animal carcasses, most blood and body fluids. Within this category, recognizable human or animal body parts are also called anatomical waste. Anatomical waste is also considered as an infectious waste, even though it may also include healthy body parts (WHO, 1999).

- Sharps are items that could cause cuts or puncture wounds, including needles, syringes, scalpels, saws, blades, broken glass and nails. Whether or not they are infected, such items are usually considered as highly hazardous healthcare waste (WHO, 1999).

- Pharmaceutical wastes include pharmaceutical products, drugs, and chemical that have been returned from wards, have been spilled, are outdated or contaminated, or are to be discarded because they are no longer required. These also include discarded items used in the handling of pharmaceuticals, such as bottles or boxes with residues, gloves, masks, connecting tubing, and drug vials (WHO, 1999).

- 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. Cytotoxic (or antineoplastic) drugs, the principal substances in this category, have the ability to kill or stop the growth of certain living cells and are used in chemotherapy of cancer. They play an important role in the therapy of various neoplastic conditions but are also finding wider application as immunosuppressive agents in organ transplantation and in treating various diseases with an immunological basis. Cytotoxic drugs are most often used in specialised departments such as oncology and radiotherapy units, whose main role is cancer treatment; however, their use in other hospital departments is increasing and they may also be used outside the hospital setting (WHO, 1999).

- 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 healthcare may be hazardous or nonhazardous; 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).

Nonhazardous chemical waste consists of chemicals with none of the above properties, such as sugars, amino acids, and certain organic and inorganic salts (WHO, 1999).

- Wastes with high heavy-metal content fall under hazardous chemical waste, and are usually highly toxic. Mercury wastes are typically generated by spillage from broken clinical equipment but their volume is decreasing with the substitution of solid-state electronic sensing instruments (thermometers, blood-pressure gauges, etc.). Whenever possible, spilled drops of mercury should be recovered. Residues from dentistry have high mercury content. Cadmium waste comes mainly from discarded batteries. Certain "reinforced wood panels" containing lead are still used in radiation proofing of X-ray and diagnostic departments. A number of drugs contain arsenic, but these are treated here as pharmaceutical waste (WHO, 1999).

- Pressurised containers consist of full or empty containers with pressurised liquids, gas or powdered materials, including gas containers and aerosol. Many types of gas are used in healthcare and are often stored in pressurised 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 (WHO, 1999).

- Radioactive wastes are wastes containing radioactive substances. These include solid, liquid, and gaseous waste contaminated with radionuclides generated from vitro analysis of body tissues and fluids, in vivo body organ imaging, tumor localisation, and therapeutic procedures (WHO, 1999).

The effect on general population can mainly be through:

- Chronic exposure, when individuals are exposed over a prolonged time to small amounts of substances in ground water, the food chain, and the air; or

- Acute exposure: when individuals are exposed for a shorter period to larger amounts. This is mainly to be from occupational exposure, when waste handlers come into contact with significant volumes of infectious waste and any reactive products.

2.2 Medical Waste Management

Medical waste management is a process that help ensures proper hygiene in the health institution and safety of healthcare workers and communities (Sanitation Connection, 2002). Johannessen *et al* (2000) opine that proper management of medical waste can minimise the risk both within and outside healthcare facilities. The first priority is to segregate wastes, preferable at the point of generation into reusable and non-reusable, hazardous and non-hazardous components. They identified other important steps as, the institution of a sharps management system, waste reduction, avoidance of hazardous substances wherever possible, ensuring worker safety, providing secure methods of waste collection and transportation, and installing safe treatment and disposal mechanisms. According to Johannessen *et al* (2000), there are generally four key steps to medical waste management: (1) segregation into various components, including reusable and safe storage in appropriate containers; (2) transportation to waste treatment and disposal sites, (3) treatment and (4) final disposal.

Acharya and Singh (2000) also identified the medical waste management process to include, handling, segregation, mutilation, disinfection, storage, transportation and final disposal. He suggests that these are vital steps for safe and scientific management of medical waste in any establishment. According to Rao, Ranyal and Sharm (2004), the key to minimisation and effective management of medical waste is segregation (separation) and identification of the waste. They recommend that the most appropriate way of identifying the categories of medical waste is by sorting the waste into colour coded plastic bags or containers. Medical waste should be segregated into containers/ bags at the point of generation. The WHO suggests that hospitals should provide plastic bags and strong plastic containers for infectious waste such as empty containers of antiseptics used in the hospital (Prüss, Giroult and Rushbrook, 1999).

General waste such as garbage and garden refuse should join the stream of domestic refuse. Sharps should be collected in puncture proof containers. Bags and containers for infectious waste should be marked with Biohazard symbol. Highly infectious waste should be sterilised by autoclaving. Cytotoxic wastes are to be collected in leak proof containers clearly labelled as cytotoxic waste (Acharya, 2000). Needles and syringes should be destroyed with the help of needle destroyer and syringe cutters provided at the point of generation. Infusion sets, bottles and gloves should be cut with curved scissors. Disinfection of sharps, soiled linen, plastic and rubber goods is to be achieved at point of generation by usage of sodium hypochlorite with minimum contact of an hour. Fresh solution should be made in each shift. On site collection requires staff to close the waste bags when they are three quarters full either by tying the neck or by sealing the bag. The storage area needs to be impermeable and hard standing with good drainage. It should provide an easy access to waste collection vehicle (Srivastava, 2000). According to scientific standards, the infectious wastes in the tropical area can be kept in a temporary storage area for 24 h during the hot season and up to 48 h in cooler seasons (Prüss *et al.*, 1999).

Medical waste should be transported within the hospital by means of wheeled trolleys, containers or carts that are not used for any other purpose. The trolleys have to be cleaned daily and designated to particular wards at the hospital. Off site transportation vehicle should be marked with the name and address of carrier. Biohazard symbol should be painted and suitable system for securing the load during transport should be ensured. Such a vehicle should be easily cleanable with rounded corners. Johannessen *et al* (2000) recommend that transportation of medical waste on public roads must be carried out by trained staff in a dedicated vehicle with closed containers.

All disposable plastic should be subjected to shredding before disposing off to vendor. Final treatment of medical waste can be done by technologies like incineration, autoclave, hydroclave or microwave (Rao *et al*, 2004).

It is important at this point to discuss the various methods of treating and disposing off medical waste

2.2.1 Medical Wastes Treatment and Disposal Methods

According to Diaz, Savage and Eggerth, (2005), some of the more common treatment and disposal methods utilised in the management of infectious healthcare wastes in developing countries are: autoclaves and retorts; microwave disinfection systems; chemical disinfections; combustion (low-, medium-, and high-technology); and disposal on land (dump site, controlled landfill, pits and sanitary landfill). These are discussed in detail below:

Autoclaves and retorts

The utility of heat, in particular moist heat, in achieving disinfection has been known for decades. Healthcare facilities have been using steam for disinfecting reusable instruments for a very long time. There are two basic types of units that utilise mainly steam for disinfecting healthcare wastes: autoclaves and retorts. The steam, required by these units, is generated by means of a boiler. The boiler can be one used for other services in the healthcare facility or it can be one specifically for the treatment of the wastes (a "dedicated boiler"). Before providing a description of autoclaves and retorts, a brief explanation of steam generation (and other parameters important in the field of steam production and heat transfer) is given so that the reader has a general appreciation of the entire process. As liquids are heated, their temperature increases until the temperature reaches what is known as its boiling point. The temperature at which a liquid boils or, in this particular case, when water is turned into steam, is called the saturation temperature. The saturation temperature of liquids is impacted by pressure; as the pressure increases, the saturation temperature also increases. At standard atmospheric pressure (100 kPa or 14.7 psia), the saturation temperature of water is 100 ^{o}C. The steam that is produced at saturation temperature is known as saturated steam (these parameters at these conditions also are known as standard temperature and pressure, or STP). In practice, steam is produced in a piece of equipment called a boiler. Usually boilers are heated by means of conventional fuels such as gas, diesel, coal, or biomass. Some boilers have also been designed to use electricity and even waste oil for heating the water. The use of waste oil requires specialised burners, and the combustion process must be carefully monitored in order to avoid substantial air emissions. Furthermore, some countries may require special permits to use waste oil as fuel (Diaz *et al,* 2005).

For safety reasons, boilers must be designed and built to withstand high temperatures and pressures. The design parameters must take into consideration a number of safety issues. The design parameters for boilers have been widely accepted around the world. To achieve optimum operation and maximum efficiency, the input water must be properly treated to reduce the buildup of salts and other compounds on the interior surfaces of the boiler; the buildup reduces the boiler's ability to transfer heat. Steam boilers are rated in horsepower, BTUs, or kW. A boiler must be properly selected such that its output (the amount and quality of the steam) will match the requirements of the particular application (in this case the autoclave or retort) (Diaz *et al,* 2005).

An autoclave essentially is a metal vessel (usually made out of steel). The vessel is hermetically sealed with a hinged door (with gaskets) and designed to resist high temperatures and pressures. Normally, a steam jacket surrounds the vessel. The steam jacket is incorporated into the design to reduce the amount of condensation on the inside wall of the vessel and thus reduce heat loss. Disinfection in an autoclave is carried out in batches. That is, the unit is loaded, disinfection carried out, and then the contents are removed from the unit. The entire process from loading to unloading is called a cycle. During a typical operation of an autoclave, the material to be disinfected is loaded into the unit and air is evacuated. Air is removed from the interior of the vessel because of the air's insulating characteristics (i.e., if air is not removed, then heat transfer to the waste would be reduced and more fuel would be required). Air generally is removed from the autoclave by using a vacuum pump at the beginning of the cycle and prior to steam injection (these units are called high-vacuum) or by relying on the fact that air is more dense than steam such that as the steam is injected into the vessel, the air has the tendency to migrate to the bottom. The air at the bottom of the vessel is removed via a drain port. The high-vacuum method is the most effective and fastest of the two. Speed in this process is important, since it reduces the overall time required per cycle. Steam is injected into both the interior of the vessel, as well as into the steam jacket (Reinhardt and Gordon, 1991; US Congress, 1990).

The retort is similar in design to the autoclave. The major difference between them is that the design of the retort does not incorporate a steam jacket, while the design of the autoclave does. The absence of a steam jacket results in inefficiencies in heat transfer and, consequently, higher temperatures are required for a retort than are required for an autoclave. Retorts normally are utilised in large-scale operations (more than about 1000 kg per day) (Reinhardt and Gordon, 1991; US Congress, 1990).

In the overall waste management process in a healthcare facility, the the waste to be treated typically is stored in plastic bags (placed inside rigid containers). The bags are collected in carts or in bins previously lined with special plastic sheeting to prevent the bags from adhering to the carts when heated. The bags should also be made of plastic that is resistant to the high temperatures inside the autoclave and at the same time be permeable to the steam in the direction toward the waste (i.e., allow the steam to penetrate the bag and go through into the waste). If an autoclave is used, at the beginning of the cycle, steam is introduced into the outer jacket of the unit (this step is known as ''pre-heating''). The loaded bins or carts are introduced into the autoclave and the door is sealed. At this point, air is evacuated from the unit either by vacuum or by introducing steam into the vessel. Steam is forced into the unit until the required temperature is achieved. Steam is added as necessary in order to maintain a prescribed temperature for a given period of time.

In some countries or states, it is necessary to record the time-temperature history for each load undergoing treatment. This generally is accomplished by means of a chart recorder. Upon reaching the necessary time–temperature requirements, vents in the unit are opened and the steam is released through a condenser (so that the water can be re-used). Once the waste has reached ambient temperatures or it is cool enough to be handled, the material is removed and taken to the disposal site or treated mechanically. Mechanical treatment generally involves size reduction, compaction, or both. From time to time, either biological or chemical indicators are inserted in waste loads in order to evaluate the degree of disinfection. To test the effectiveness of the process, spores of Bacillus stearothermophilus are placed in the waste as it is introduced into the autoclave and removed after the process is finished. The spores are collected and incubated for about a week. The spores are available commercially in disks, strips, or in ampules (Reinhardt and Gordon, 1991).

Autoclaves and retorts generally are used to treat materials, such as; sharps; cultures; items contaminated with blood; residues from surgery and from isolation wards; bandages, gauze, linen, gowns, and other similar materials (also known as ''softs''); and non-chemical laboratory wastes. In some special circumstances, it is technically possible to disinfect body parts. However, in the case of items with a large mass, care must be taken to achieve the necessary time–temperature relationships. In addition, any time that body parts are treated in an autoclave, cultural, ethical, legal, and other factors must be taken into consideration.

Healthcare facilities also produce a variety of chemical and hazardous substances that should not be treated in an autoclave. These types of wastes include: wastes from chemotherapy treatment, mercury, volatile and other hazardous chemical wastes. In general, it is not advisable to treat large body parts, animal carcasses, or other large items that, because of their mass and other characteristics, make it difficult or time consuming for the entire material to reach the prescribed temperatures. Waste materials that are treated in an autoclave do not change considerably from their original state. Waste that is treated in an autoclave would look essentially the same as it did prior to the treatment. In fact, depending upon the type of unit, the mass of the waste may increase due to the addition of water. Consequently, in order to meet the requirements of local regulations, some manufacturers incorporate into their systems some type of mechanical processing and, most commonly, size reduction, compaction, or both. Size reduction essentially changes the appearance of the waste and increases the bulk density of the mixture, thereby reducing the volume that the mass would occupy by 60–80%. In addition to the treated solid matter, a typical autoclave would release liquid and gaseous discharges. Both of these discharges must be properly managed prior to release into the environment (Diaz, Savage, Eggerth and Golueke, 2003).

Microwave disinfection systems

This involves the application over the waste of a high energy electromagnetic field that provokes the liquid contained within the waste, as well as the liquid cell material of microorganisms, to oscillate at high frequency, heat up rapidly and eventually cause the destruction of all infectious components of the waste (Johannessen *et al*, 2000).

Microwaves are very short waves in the electromagnetic spectrum and are within the range of the radio frequency band. Microwaves have wavelengths in the centimetre range and fall below the range for infrared (IR) waves and above the ultra-high frequency (UHF) waves used for television. Microwaves typically are generated by means of magnetrons. However, they can also be generated by klystrons, or travelling wave oscillators. All of these units essentially convert electrical energy into microwave energy. The microwaves are then guided into a metallic channel known as the "wave guide". The guide focuses the microwaves into a particular location. Microwaves cycle very quickly between positive and negative, and at a very high frequency (around 2.4 billion times per second). The high frequency makes the molecules in the receiving body (liquid or solid) vibrate very rapidly as they attempt to align to the changing electromagnetic field. The very high level of vibration results in friction. The friction generates substantial amounts of heat (Reinhardt and Gordon, 1991; US Congress, 1990). It has been demonstrated that disinfection in microwave units is not a result of exposure of material to the microwaves. The steam produced from the moisture in the waste by the microwave energy brings about the destruction of the pathogenic organisms in the waste. Consequently, microwave systems in the healthcare waste sector typically require the addition of water (or steam) into the waste during the treatment process.

Microwave disinfection systems typically consist of three major types of equipment: (1) material handling equipment, (2) the disinfection equipment itself, and (3) environmental control equipment. The disinfection area or enclosure includes a hermetically enclosed chamber, where the materials to be treated are placed and into which the microwaves are focused. Microwave systems are designed and built in a variety of sizes, ranging from a few kg per hour to more than 400 kg per hour. The units can be operated as a batch process or in a semi-continuous mode. Large-scale systems can have from 1 to 6 microwave generators (magnetrons). Generally, each magnetron has a power output on the order of 1.2 kW. The waste to be treated is placed in carts and transported to the treatment facility. The carts are lifted by a hydraulic mechanism, a gate that seals the hopper opens, and the waste is discharged into the hopper. As the waste is introduced into the hopper, steam is injected into the hopper and air is extracted from the unit. All extracted air is passed through a high efficiency particulate air (HEPA) filter. The waste in the hopper is forced into a shredder. The shredded waste is transported via a rotating screw, exposed to steam, and then heated to between 95°C and 100°C by means of microwaves. The treated waste may be passed through a secondary shredder to achieve a higher degree of particle size reduction than with only one shredder. Secondary size reduction is particularly important in the event that sharps are part of the waste stream (Diaz *et al*, 2003).

Chemical disinfection

Chemical disinfectants have been utilised in the healthcare sector for many years. Disinfectants have been used in a variety of applications, from preparing a particular area in the body prior to an injection, to cleaning surfaces in the working areas. Chemical disinfection has also been applied to the treatment of healthcare wastes. In this section, various options of chemical disinfection of healthcare waste are discussed. Chemical disinfection relies on the particular properties of the chemical agent to inactivate pathological organisms. The effectiveness of a certain chemical agent depends upon temperature, pH, and on the possible presence of other compounds, which can have a negative impact on the effectiveness of the chemical agent. Any or all of these factors play a role in the ability of the chemical agent to act on the cells of the particular microorganism. Furthermore, it has been determined that some microorganisms are more resistant to chemical treatment than others. The most resistant microorganisms to chemical treatment include bacterial spores and hydrophilic viruses. On the other hand, some of the least resistant to chemical treatment include fungal spores and vegetative bacteria.

Antimicrobial agents act at the cellular and at the molecular levels. At the cellular level, these agents can damage the cell wall or the membrane of the cell. On the other hand, at the molecular level, antimicrobial agents can alter protein and DNA synthesis or cause inhibition through enzymatic reactions. Chemical methods of microbial control include antiseptics and disinfectants, which are non-specific for the cells that they affect. Antiseptics are used on animate objects, while disinfectants are used on inanimate objects. Sterilisation can be achieved by using several chemical compounds in the gaseous form. These compounds, such as formaldehyde and ethylene oxide, are extremely toxic. A variety of chemicals can be used to achieve chemical disinfection; some of these chemicals include: alcohols, acids, alkalis, phenols, halogens, heavy metal compounds, detergents (including quaternary ammonium compounds), anti-metabolites, and peroxides. Ideally, a disinfectant should have the following characteristics:

- capable of destroying all microorganisms as well as viruses;

- possess a high degree of stability;
- not be toxic to humans or to animals;
- be soluble in water;
- be tasteless and odorless; and
- be relatively inexpensive.

Acids and bases are effective disinfecting compounds because they release hydrogen (acids) and hydroxyl ions (bases). Enzymes are very sensitive to pH and are inactivated by very acidic or very basic compounds. Some of the types of disinfectants and antiseptics are mentioned below (Meyer, 1997).

Alcohols are compounds that are usually used as skin antiseptics. Alcohols are surfactants and also coagulate proteins. Ethanol, isopropanol, and benzyl alcohol are effective at concentrations of 50–70%. Alcohols are not effective in destroying, fungi, spores, or most viruses. Phenol (carbolic acid) and its derivatives (cresol, orthophenylphenol, and others) are used for sterilizing surfaces (Diaz *et al* (2005).

Phenols act mostly by coagulating and damaging the plasma membranes. They tend to remain on surfaces. The effectiveness of phenols is similar to that of alcohols. The strengths of new disinfectants are expressed by comparison to phenol. This is known as the phenol coefficient (Diaz *et al,* 2005).

Halogens, especially iodine and chlorine, are widely used as antiseptics and disinfectants. Iodine and chlorine are lethal to a large variety of fungi, bacteria, and viruses through the inactivation of proteins. Tincture of iodine (a solution of 1–2% iodine in alcohol) is widely used for wounds. The iodine reacts with hydroxyl groups and inactivates proteins. Chlorine gas reacts with water to form hydrochloric acid (HCl) and hydrogen peroxide. Both of these compounds destroy microbial cells. They have been commonly used to disinfect public water supplies and sewage, and they have been widely used in the dairy industry. Common household bleach consists of 5.25% sodium hypochlorite.

Aldehydes such as formaldehyde (8%) and glutaraldehyde (2%) are alkylating agents that react with amines, some groups of proteins (such as sulfhydryl and carboxyl), and small organic molecules to inactivate them. Aldehydes essentially destroy all forms of microbial life, but their application is limited due to their noxious vapors.

Heavy metals precipitate proteins and therefore are effective as antimicrobial agents. Silver nitrate is used in the eyes of newborn babies, copper sulfate has been used in swimming pools, and some mercury compounds are used in the clothing and flower industries. Merbromin (mercurochrome) has been used extensively as an antiseptic. Heavy metal compounds are primarily bactericidal.

Detergents include soaps and synthetic detergents. Soaps are potassium or sodium salts of high fatty acid content. Detergents are mainly surfactants and are used to wash away debris from surfaces. Synthetic detergents are manufactured such that they have some soap properties. Essentially, there are three types of detergents: (1) anionic detergents (e.g., sodium lauryl sulfate); (2) cationic detergents (e.g., alkybenzyl sulfonates) and quaternary ammonium compounds (such as zeepryn and zephiran) are effective against bacteria and fungi; and (3) non-ionic detergents.

Gases, due to their ability to penetrate in a closed system, are excellent disinfectants and are effective against all forms of microbial life. Some of the gases that are most commonly used are ethylene oxide, propylene oxide, and *b*-propiolactone. Sulfur dioxide is commonly used as a food preservative.

Hydrogen peroxide (H_2O_2) is a mild antiseptic. Hydrogen peroxide is commonly used on wounds to destroy anaerobic bacteria.

Some of the most common chemical disinfectants used in the treatment of healthcare waste used to be chlorine-based. Of these, sodium hypochlorite (commonly known as bleach) was formerly one of the commonest solutions used for disinfection. However, due to chlorine's negative health effects and since it has been demonstrated that chlorine is a precursor to the formation of dioxins in combustion; non-chlorinebased disinfectants are now being used. Some of these alternatives include: aldehydes (such as formaldehyde and glutaraldehyde), calcium oxide, ozone, and others. Calcium oxide (lime) generally is applied to healthcare wastes and other organic residues at disposal sites in developing countries. Lime added in sufficient quantities raises the pH to 11 or higher. A high (i.e. alkaline) pH creates an environment that inhibits the survival of microorganisms. In such an environment, the residues will not generate unpleasant odors or break down as long as the pH is maintained at the requisite high level. Quickly covering the waste/lime mixtures with soil at the disposal sites, helps preserve the advantages of the highly alkaline environment. When lime is added to the waste, adequate personal protection should be given to the workers applying the lime. Also, liquid discharges from the area must be carefully monitored and managed.

Some of the more important requirements to achieving efficient and productive chemical treatment of healthcare wastes are: (1) sufficiently high concentration of the chemical agent, (2) sufficient time in which the wastes are in contact with the chemical agent (retention time), and (3) waste with small particle sizes. Small- and large-scale systems have been designed and used for chemical treatment of healthcare wastes. These systems typically incorporate some type of size reduction equipment to shred the wastes before chemical treatment. The chemical that has been used in the past for disinfection is a solution of chlorine. Subsequently, the treated solids are separated from the liquids. The addition of a liquid into the system means that eventually the liquid has to be managed prior to discharge into the environment. In the past, the liquid used is discharged into the sewerage system. At some locations, a special permit must be obtained for this type of discharge. In other situations, it may be necessary to treat the liquid prior to discharge into the sewer (because of the concentrations of metals, organic contaminants, dissolved solids, and others). Aerosols and particulate matter that may be released from the process are managed by means of air pollution control devices, which include: enclosures, ducting, HEPA filters, and blowers providing negative pressure.

Chemical disinfectants generally are used to treat such materials as: sharps; cultures and stocks; items contaminated with blood, liquid human and animal wastes; residues from surgery and from isolation wards; bandages, gauze, linen, gowns, and other similar materials; and non-chemical laboratory wastes. Healthcare facilities also produce a variety of chemical and hazardous substances that should not be treated with chemical compounds. These types of wastes include: wastes from chemotherapy treatment; mercury; volatile and semi-volatile organic compounds; radioactive wastes; and other hazardous chemical wastes. In general, it is not advisable to treat large body parts, animal carcasses, or other large items that, because of their mass and other characteristics, make it difficult or costly for the entire material to be properly treated.

In several healthcare facilities in developing countries, it is common practice to use a recycled container from within the hospital that is partially filled with a chemical disinfectant (usually a solution of sodium hypochlorite) to store used needles prior to disposal. This practice presents a risk to the medical staff and other personnel in the facility just by the mere fact that the containers must be filled. This compound and others of similar characteristics are, at the very least, strong irritants to the skin and to the respiratory system. Furthermore, it has also been observed that at the time of collection, the containers with disinfectant and sharps are simply capped and taken to the storage facility prior to treatment or final disposal. Thus, the liquid remains in the container. The presence of sodium hypochlorite can cause occupational health problems and, in the event that the wastes are treated in an incinerator, it contributes to the formation of dioxins and furans. The treatment facility can also pose occupational hazards because chemical processes generally require some type of size reduction of the treated waste. Thus, there is the possibility of pathogen release through the formation of aerosols (Diaz *et al*, 2003).

Combustion

Infectious healthcare waste may also be treated by combusting it in a variety of methods. The "vessels" used for the combustion process range from simple open pits in the ground, to metal drums, to sophisticated units that incorporate specialised equipment to control emissions from the process. Any method used for the combustion of solid wastes generally produces three types of discharges: gaseous, liquid, and solid. The exception would be the use of combustion in the open air, in which case water may not be used to quench the hot ashes. In a conventional modern solid waste-fired incinerator, equipped with air pollution control equipment, concentrations of heavy metals and dioxins would be present in the fine solid removed from the stack gas (fly ash). In some countries, the fly ash collected from incinerators treating municipal solid waste is considered a hazardous waste. In this discussion, the combustion technologies are divided into three general types: low, medium, and high technologies (Brunner, 1996).

With respect to the low-technology combustion, it is common to find that, in many developing countries, some fractions of healthcare wastes, and in particular used injection equipment, are commonly burned in the open air or in simple (and oftentimes improvised) units such as pits, burners (made out of brick or cement), and in drums. The units obviously are relatively inexpensive, are easy to build, and require little or no maintenance. Because of the relatively uncontrolled conditions under which the combustion takes place, the process reaches only what is considered to be low temperatures (about 400°C or below). Combustion at these temperatures does not completely burn all of the wastes, particularly if the wastes contain relatively high moisture content. Some syringes and needles may remain relatively unchanged at the completion of the combustion process. Furthermore, the uncontrolled process may not destroy all of the pathogens. This type of combustion does not control any type of emissions (particulate matter, heavy metals, and others) and, in fact, may lead to the production of relatively high concentrations of toxic organic compounds. Whole vaccine vials and similar glass containers have the tendency to explode and thus pose an additional risk to the person tending to the combustion process.

Medium-technology combustion is defined as that which in some manner attempts to control the combustion process and, therefore, provides slightly better air pollutant control than that achieved by the low-technology options. There are some relatively simple and not excessively expensive units available in the marketplace that fit into this category. In essence, the units generally have a small capacity, are operated in batches, and do not include any type of air pollution control equipment. High-technology combustion is defined as the combustion of healthcare waste under controlled conditions, using equipment that operates at temperatures on the order of 900–1000°C, and that includes air pollution control equipment as well as other components to manage the emissions from the unit. These units generally include a second chamber (known as secondary chamber) in which the off (by-product) gases from the first chamber are treated at high temperatures by means of an ancillary burner. High-technology combustion essentially provides the necessary conditions (temperature, time, and turbulence) to achieve complete combustion and to keep the concentration of undesirable compounds to a minimum. These types of incinerators operating in developing countries do not usually have postcombustion air pollution control systems. The auxiliary fuel for these types of incinerators is diesel or gas. The incinerator may be operated in batch or continuous modes (Diaz *et al*, 2003).

The direct combustion (incineration) of medical waste generates particulate matter and chemical compounds that can potentially affect human health and safety and have a negative impact on the environment. These materials can be emitted in gaseous, liquid, or solid form, and the impacts to humans can be direct (through inhalation of the emissions) or indirect (by ingesting items upon which particulate matter may have settled).

Land disposal

Land disposition of medical waste is performed in the same manner as municipal solid waste. In general, land disposal of municipal solid wastes can be divided into three methods: open dumps, controlled landfills, and sanitary landfills. Landfill is the deposition of waste in a specially designated area, which in modern sites consists of a pre-constructed 'cell' lined with an impermeable layer (man-made or natural) and with controls to minimise emissions. This, also known as the traditional solid waste management practice, has been characterised by the frequently irresponsible dumping of complex mixed and toxic solid wastes in landfill sites. Additionally, toxic liquids and slurries contained in corrosion-prone metal drums have frequently been buried in landfills or have been subject to marine dumping. Until in recent times, solid waste segregation at source and refusal to accept hazardous materials for landfill and landfill site licensing have been largely unknown. Historically, landfill site selection was based on both proximity to waste production and the availability of large pits, which were usually the result of quarrying or gravel, sand or brick–clay extraction, rather than on geological criteria of site suitability. The primary operational criterion for traditional landfills was disposal at minimum immediate cost, a depository type of approach that sought to ignore future problems, particularly containment failures, the discovery of toxic hot spots and the resultant effects of partial degradation, which in recent times have been responsible, in many cases, for substantial remediation requirements (Diaz *et al*, 2003).

The method used to dispose of treated or untreated healthcare wastes in developing countries depends on the type of disposal facility available. Facilities vary from open dumps, to controlled landfills, to sanitary landfills. Due to the prevalence of land disposal of medical waste in developing countries, it is important to discuss the more common, special techniques available for disposal of solid wastes, medical waste, or both (Diaz *et al*, 2003).

At the present time, the most common method of land disposal of solid wastes in developing countries is the open dump. Because of the uncontrolled nature of disposal, this method obviously is the least costly option, but at the same time, it is the one that causes the most negative impacts to the public and the environment.

The controlled landfill which is a land disposal facility that: is sited according to basic hydrogeological conditions; restricts access to the area by means of a fence or a similar structure; controls scavenging; keeps waste discharges to a small working area; makes use of a soil cover on a regular basis; controls surface water and drainage; maintains basic records; manages the landfill gas; and applies a final cover and vegetation once filled.

The sanitary landfill is an engineered waste disposal facility that, among other aspects, includes in its design: sitting in accordance with hydrological, geological, social, and other factors; a bottom liner composed of a natural or synthetic layer of a low permeability material; measures to ensure that leachate and landfill gas are collected and properly managed; groundwater monitoring wells; use of daily, intermediate, and final covers; and a comprehensive closure and post-closure plan (Diaz *et al*, 2003).

Traditional landfills were always associated with operational difficulties such as noxious gas and vapour, dust and leachate production, as well as rodent infestation and, even today, modern engineered landfills are perceived to have similar problems as a result of their acceptance of readily biodegradable solid waste that constitute either an available food source, in the case of rodents, or feedstocks for anaerobic biodegradation, the primary source of noxious gaseous emissions that migrate within and are released from landfills. Biogas production from waste is a subject that is emotionally, but not necessarily, economically attractive. Methane is the end product of anaerobic digestion of biodegradable organic matter. Most modern engineered landfills have been designed for biogas production by undersealing and capping and installing both appropriately designed wellheads for gas collection and appropriate leachate collection and treatment facilities. Landfill biogas typically contains between 48% and 56% methane and has, therefore, in its produced form a calorific value of approximately half that of natural gas, as supplied from distribution networks. The project life for economic landfill biogas production is typically 10 years, but residual production can be expected to last for more than 40 years. For economic operation, landfill biogas must, from all but the very largest installations, have a captive market that does not require gas cleaning and purification. Examples of such markets are cement and brick kilns. For very large installations, where diverse uses for the gas produced are envisaged, both calorific value upgrading and purification procedures for moisture, carbon dioxide, hydrogen sulphide and halogenated hydrocarbon removal (Dernbach and Henning, 1987) are essential ancillary facilities for the methane to realise its market price. A well-known feature of traditional landfills containing potentially biodegradable matter has been major spatial variations in biodegradative activity as a result of a lack of system design. But in more recent times, with the advent of engineered landfills, the requirement for optimisation to maintain anaerobic biodegradation and possibly enhance biogas production rates is recognised.

Some of the operating conditions that were identified as impacting on process rates were the need for elevated moisture contents and elevated moisture throughputs by leachate recirculation, pH control/buffer addition, nutrient addition, anaerobic sewage sludge inoculation and elevation of the operating temperature (Kinman, Nutini, Walsh, Vogt, Stamm and Rickabaugh, 1987). However, the practicability of some of these proposals is questionable and, clearly, others could introduce deleterious side effects with respect to overall system operation. Both the potential environmental impact of massive engineered landfills for the degradation of biodegradable organic wastes and their extended, but declining rate of residual biogas production, seems to suggest that landfills provide only an interim solution for biodegradable solid waste management. In the future, landfills would seem to be only appropriate for essentially stable wastes such as that derived from construction and demolition or from incineration. But even here, avoidance of dust, particularly in situations where asbestos or sorbed carcinogens are present, is paramount. If landfill is not to be used for biodegradable solid waste and slurry disposal, the critical question that arises is: What economically viable and safe alternative large scale processes exist that will satisfy legislation and will be acceptable to the general public? The two most widely discussed options are biotreatment and incineration. It must be noted, however, that both require waste segregation either at source or immediately before processing (Hamer, 2003).

The advantages and disadvantages of the various medical waste management methods are summarised in Table 2.1.

Table 2.1: Medical Waste Management Methods – Key Advantages and Disadvantages

Option	Advantages	Disadvantages
Autoclaves and retorts	▪ Simple to operate. ▪ A known technology at healthcare facilities.	▪ Relatively expensive to install and operate. ▪ Requires boiler with stack emissions controls ▪ Cannot be used to treat some hazardous wastes, pharmaceuticals, and cytotoxics. ▪ Requires separate and additional packaging. ▪ Generates odors ▪ Final disposal must be as for untreated special medical waste. ▪ Generate contaminated waste water that needs treatment.
Microwave disinfection system	▪ The shredding process reduces the volume of the waste (not mass).	▪ Highly sophisticated and complex ▪ Relatively expensive to install. ▪ Only solids can be treated and only when shredded. ▪ Cannot be used to treat some hazardous wastes, pharmaceuticals and cytotoxics. ▪ Highly skilled operator required.

		▪ Expensive and difficult to maintain. ▪ Final disposal must be same as for untreated special medical waste. ▪ Generates contaminated waste water that needs treatment.
Chemical disinfection	▪ The shredding process reduces the volume of the waste (not mass).	▪ Cannot be used to treat some hazardous wastes, pharmaceuticals and cytotoxics. ▪ Highly skilled operator required. ▪ Expensive and difficult to maintain. ▪ Final disposal must be same as for untreated special medical waste. ▪ Generates hazardous water that needs treatment.
Combustion	▪ Elimination of health risks. ▪ Waste is non-recognisable. ▪ Fully destroys micro-organisms and sharps. ▪ Reduces volume/mass of the waste. ▪ Destroys all types of	▪ High investment costs. ▪ Complicated to operate. ▪ Continuous monitoring required. ▪ High maintainances, especially for rotary kilns ▪ Relatively high operation costs; costs rise with the level of sophication of the emission controls system. ▪ Emits toxic flues gasses.

	organic waste. ▪ Heat recovery possible. ▪ High quantities of waste can be treated (except for batch incinerator).	▪ Generates residue that needs safe landfilling. ▪ Any residue generated may be toxic.
Land disposal	▪ Simple and inexpensive to operate. ▪ No specific construction costs required. ▪ Operates within readily available landfill system. ▪ Waste pickers are unable to access the special medical waste.	▪ Special medical waste is not treated and preserves potential infectiousness. ▪ High demand for coordination between collector and landfill operator. ▪ Reduces awareness among healthcare workers of need to segregate waste types. ▪ Potentially, long transportation to landfill.

(Johannessen *et al*, 2000)

In addition, residues from immunisation programmes (primarily needles and syringes) generally are managed through: burial in specific pits with a cover and encapsulation by means of immobilising compounds (primarily cement and plastics).

Burial in special pits

Burial of medical waste in special pits is particularly applicable to relatively small healthcare facilities located in isolated (rural) areas where the geological and hydrological conditions are suitable and the area is sparsely populated. Suitability depends upon the amount of waste generated, the type of soil in the area, the distance to groundwater, and the distance to the nearest receptor. Typically, the pit is about 2–3m deep and approximately 2m wide. If possible, the entire pit should be lined with a 30cm layer of compacted clay or any other suitable low permeability material. If sufficient quantities of the impermeable material are not readily available, then only the bottom of the pit should be lined such that percolation of any liquids into the soil underneath is reduced to a minimum. The top portion of the pit should be slightly elevated and properly sloped to keep surface waters from entering the pit. Ideally, the pit should be covered with a simple, but sturdy removable cover. The pit should be built by persons knowledgeable in construction so that it is built efficiently and, most importantly, to prevent the sides from collapsing.

The entire disposal area should be properly fenced in order to keep unauthorised personnel or animals from entering into the area. This type of pit may be used by small healthcare facilities, but may not be suitable for large-scale immunisation programmes due to the large number of used needles and syringes that would be generated. Once the pit is full, the top opening should be sealed with soil or with cement and the area clearly identified. If sufficient funds are available, the pit should preferably be constructed entirely out of cement, much like a septic tank, including a solid cover. The pit or vault can be built with a hinged, lockable cover for additional security.

Encapsulation

Encapsulation is a procedure that has been widely used in the field of hazardous waste management, and it is a procedure that can be used for the treatment of sharps and more specifically hypodermic needles. In the process, the sharps are placed in containers. The containers can be made out of cardboard, plastic, or metal. The size of the containers varies from a fraction of a litre to about 100 litres. When the containers are almost full, a material known to immobilise the sharps is added. The most common materials that are used to immobilise the sharps are cement, plastic foams, resins, and clay. Once the immobilizing material is dry or has hardened, the container is properly sealed and disposed.

Disposal can take place in a municipal disposal site or through on-site burial. Cement encapsulation can also be used to dispose of sharps generated by large immunisation programmes, either using large containers as described in the previous section or by building a sufficiently large pit to accommodate the wastes. In this particular case, it is important to calculate the size of the pit or trench that will be required to hold the "volume" of needles and syringes produced. The wastes are carefully placed in the pit. If a flexible membrane is used to line the pit, then the sharps should be contained in boxes or similar containers to avoid punctures of the liner. Once all of the sharps are in the pit, the cement mixture is added. For optimum results, the mixture is prepared as follows:

- 1 part cement;
- 1 part lime;
- 4 parts sand; and
- 1/2 part water.

A sufficient quantity of this mixture is added to enclose the entire mass of waste in the pit. After the mixture is set or hardened, the pit is covered with soil, properly contoured to reduce the amount of water infiltration, and identified to denote the type of waste buried on the site. This process is relatively inexpensive and uses a simple technology. In addition, encapsulation keeps personnel in the waste management system and scavengers at the disposal sites from accessing the materials and from being injured. No data have been found on the survival of microorganisms under encapsulation conditions.

Immunisation programmes generally incorporate the use of safety boxes or sharps containers for the temporary storage of used needles, syringes, and other sharps. These boxes or containers are composed of materials that are impermeable and resistant to punctures. Used syringes, needles, and other contaminated sharps are placed in these boxes. Once the boxes are approximately 75% full, they are secured and stored in a safe location until the boxes and their contents can be properly treated or disposed. Ideally, safety boxes should be filled only once and destroyed. Safety boxes generally range in size from 5 to 20 litres.

Diaz *et al* (2005) however caution that, there is no single method of waste treatment or disposal that completely eliminates all risks to the public or to the environment. In general, depending upon the type of technology, the residues are transformed from one phase to another. For example, in incineration, the combustible components of the wastes are converted into gaseous byproducts (CO_2, H_2O_2, CO, and other gases, some of which are toxic) and non-combustible components remain as solid byproduct, namely ash. With respect to risk reduction associated with microorganisms, the most important objective is to destroy them prior to release of the contaminated material into the environment. Pathogen destruction can be achieved through proper thermal, chemical, and irradiative treatment.

2.3 Medical Waste Management versus Municipal Solid Waste

Methods of managing medical waste are different from that of municipal solid waste. The old technologies for municipal solid waste comprise of landfilling, composting, recycle and waste-to-energy technologies. Such methods are not totally applicable to medical waste except recycle and waste energy under well-planned management systems. Medical waste cannot be introduced into a waste-to-energy system or any other municipal solid waste combustion system because treatment of these two waste types needs different levels of care. Moreover, staff trained to burn municipal solid waste cannot perform medical waste incineration until they receive special training. In developing countries, hospitals adopt management methods pertaining to municipal solid waste like open pit burning and pit burying (Manyele *et al*, 2003).

The first principle of medical waste management is waste reduction, which means reducing the quantity and toxicity of waste at the source. This comprises of eliminating or substituting substances that pose risk in the medical waste management with those that do not. Minimizing the amount of waste (by good housekeeping) and waste auditing (characterisation, planning and education) are the best techniques for municipal solid waste. The key players for effective medical waste reduction are manufacturers and consumers of medical facilities (pharmaceuticals, equipment, packaging, etc.). Another principle of proper municipal solid waste combines waste segregation and recycling of useful materials. It should be noted that pathological and/or infectious waste is a small fraction of the total hospital waste volume, while the waste paper, cardboard and food remains comprise of the large portion. The latter is indirectly related to the patient care and can be easily handled. Through waste segregation, useful materials can be recovered out of the uncontaminated portion, example, cardboard, paper, glass, plastics, cans, and bottles. However, as mentioned earlier, recovery of useful material requires well-planned waste management programmes. Such efforts have been recently reported in Pakistan (Ahmed, 1997) and India (Iyer, 2001). For effective waste segregation and recycling, the hospital management needs to focus on the non-patient waste portion.

Currently, there is strong inhibition towards hospital recyclables in the society. This is self-defence of the society, an advantageous nature of the human kind. Knowing that our medical staff are not well trained in the recycling of useful material, the society is not likely to indulge in this business. This is why the recyclables from hospitals are highly discriminated. To make the society accept recycled items from medical waste and get involved in the recycling business, one must clearly show them that the materials are harmless and show clearly the advantages of the business. For the time being, however, the knowledge and practice is still low, so that, recycling of medical waste should not be entertained. It should be borne in mind that sharps are not candidates for recycling.

As the separation of hazardous waste from domestic waste is often not carried out properly, the domestic waste of hospital cannot be compared with the common city waste. Therefore, due to the intermingling of hazardous waste, these wastes are considered infectious and the appropriate treatment method used (Department of Health, New York State, 1995).

For proper medical waste management, several challenging issues must be overcome. Each hospital, for example, must establish the correct amounts and composition of the wastes they generate. During immunisation campaigns, for instance, the medical waste management staff needs to take an extra care. The wastes generated during such campaigns have different classes depending on the mode of classification. The classification of sharps and softs on weight and volume basis shows that sharps are still a small portion of the waste, but which requires special care compared to the softs (Lloyd, 2003; Manyele, Anicetus and Bilia, 2003).

2.4 Public Health Effects of Medical Waste

Medical waste includes a large component of general waste and a smaller proportion of hazardous waste. Exposure to hazardous medical waste can result in disease or injury. According to the WHO (1999), the hazardous nature of medical waste may be due to one or more of the following characteristics:

- It contains infectious agents
- It is genetoxic
- It contains toxic or hazardous chemicals or pharmaceuticals
- It is radioactive
- It contains sharps

All persons exposed to hazardous medical waste are potentially at risk, including those within the healthcare institutions that generate the 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 mostly at risk of hazardous medical waste include:

- medical doctors, nurses, healthcare auxiliaries, and hospital maintenance personnel
- patients in healthcare establishments or receiving home care
- visitors to healthcare establishments
- workers in support services allied to healthcare establishments, such as laundries, waste handling, and transportation

- workers in waste disposal facilities (such as landfills or incinerators), including scavengers

Prüss *et al* (1999) identified the health impacts of various forms of medical wastes. These are discussed below.

2.4.1 Effects of Infectious Waste and Sharps

WHO has estimated the amount of infectious waste and sharp objects in developing countries to be about 15% and 1%, respectively (Prüss *et al.*, 1999). For serious virus infections such as HIV/AIDS and hepatitis B and C, healthcare 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 healthcare 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. Certain infections, however, spread through other media or caused by more resilient agents, may pose a significant risk to the general public and to hospital patients. For instance, uncontrolled discharges of sewage from field hospitals treating cholera patients have been strongly implicated in cholera epidemics in some Latin American countries.

2.4.2 Effects of Chemical and Pharmaceutical Waste

While there is no scientifically documented incidence of widespread illnesses among the general public due to chemical or pharmaceutical waste from hospitals, many examples may be found of extensive intoxication caused by industrial chemical waste. Moreover, many cases of injury or intoxication result from the improper handling of chemicals or pharmaceuticals in healthcare establishments. Pharmacists, anaesthetists, nurses, auxiliary staff, and maintenance personnel may be at risk of respiratory or dermal diseases caused by exposure to such substances as vapours, aerosols, and liquids. To minimise this type of occupational risk, less hazardous chemicals should be substituted whenever possible and protective equipment should be provided to all personnel likely to be exposed. 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.

2.4.3 Effects of Genotoxic Waste

To date there is little data on the long-term health impacts of genotoxic healthcare waste. This is partly because of the difficulty of assessing human exposure to this type of compound. A study undertaken in Finland, for example, found a significant correlation between fetal loss and occupational exposure to antineoplastic drugs during the first three months of pregnancy. However, similar studies in France and the USA failed to confirm this result. Some 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. The concentration of cytotoxic drugs in the air inside hospitals has been examined in a number of studies designed to evaluate health risks linked to such exposure (see Pyy, Sorsa, Hakala, 1988; Sessink, 1992).

2.4.4 *Effects of Radioactive Waste*

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. However, few reliable scientific data are available on the impact of radioactive hospital waste. It may be that many cases of exposure to radioactive healthcare waste, and associated health problems, go unreported.

2.4.5 *Risk to the General Public*

Potential health effects from exposure to medical waste are numerous. Infections may be transmitted by contact with patients' excretions or body fluids contained in the waste. Pathogens may also be distributed by rodents and insects that come in contact with unsafely stored waste. Poor management of medical waste is also suspected to contribute to nosocomial infections when the waste contaminates patients items or surfaces. Other potential health effects include gastroentric infections, respiratory infections, blood stream infections, skin infections, effects of radioactive substances and intoxication. (WHO, 2005).

The reuse of infectious syringes represents a major threat to public health. Based on previous estimates (Kane, Lloyd, Zaffran, Simonsen and Kane, 1999) and recent updates, WHO estimated that in 2000 worldwide, injections undertaken with contaminated syringes caused about 23 million infections of Hepatitis B and Hepatitis C and HIV. Such situations are very likely to happen when healthcare waste is dumped on uncontrolled sites where it can be easily accessed by the public: children are particularly at risk of coming into contact with infectious wastes. The contact with toxic chemicals, such as disinfectants may cause accidents when they are accessible to the public. In 2002, the results of a WHO assessment conducted in 22 developing countries showed that the proportion of healthcare facilities that do not use proper waste disposal methods range from 18% to 64% (WHO, 2005). Clearly, there are strong links between medical waste management and hospital hygiene.

2.4.6 Risk to the Environment

In addition to health risks derived from direct contact, healthcare waste can adversely impact human health by contaminating water bodies during waste treatment, and by polluting the air through emissions of highly toxic gases during incineration. When wastes are disposed of in a pit which is not lined or too close to water sources, the water bodies may become contaminated. If healthcare waste is burned openly or in an incinerator with no emission control (which is the case with the majority of incinerators in developing countries), dioxins and furans and other toxic air pollutants may be produced. This would cause serious illness in people who inhale this air. When selecting a treatment or a disposal method for HCW, the environmental viability is thus a crucial criterion. WHO has established tolerable intake limits for dioxins and furans, but not for emissions. The latter must be set within the national context. A number of countries have defined emission limits. They range from 0.1 ng TEQ/m3 (Toxicity Equivalence) in

Europe to 0.1 ng to 5 ng TEQ/m3 in Japan, according to incinerator capacity (WHO, 2005). However, it must be noted that incineration is now a least preferred option in the Europeon Union.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

This chapter deals with the sample, research design used, ethical consideration, data analysis and the limitations of the study.

3.1 Sample

This study is a case study of one major hospital in South Africa. Tygerberg Hospital in the Cape Metropolis was selected in order to characterise the medical wastes in a local context. Tygerberg Hospital is chosen because it is one of the leading health institutions in the country and in the Western Cape Province. The hospital is located specifically in the City of Cape Town and is one of the oldest, largest, most advanced, and comprehensive medical compounds in South Africa. Therefore, it is expected that the level of awareness of the importance of the proper handling of medical waste will be higher than other hospitals in the country. As a teaching hospital, Tygerberg Hospital comprises many departments, such as the wards, the casualty, the minor operating theatre, the major operating theatre, a maternity section, the laboratory, and X-ray section among others.

3.2 Research Design

The methodology adopted for this study follows that used by Oweis *et al* (2005). This includes a two-stage strategy:

1. Examining the rules, procedures, and regulations set forth by the hospital's directory to be followed by the personnel regarding the management of medical waste generated at the hospital.
2. Spending enough time in the different departments of the hospital recording observations and writing notes in a critical manner about the practices of medical waste management by staff responsible for waste management.

The researcher made five visits to the hospital, taking note of how medical waste was managed. Regular visits were made to general medical wards, maternity wards, surgical and critical care wards, operating theatres, and orthopaedic sections. It was observed that about 65% of the medical waste is generated in the general medical wards.

The researcher also made use of both primary and secondary data. Secondary data was obtained from the hospital's documents. Information was also obtained from published and unpublished books, journals, newsletters, periodicals, articles and the Internet. Primary data was collected from questionnaire administration and interviews with two authorities of the hospital, four health workers and four personnel in charge of infection control and waste management at the hospital. In all ten personnel at the Tygerberg

Hospital were interviewed. Based on the recommendations of the World Health Organisation for evaluation of hospital waste management in developing countries, (Prüss *et al.*, 1999, WHO, 1999) a data form and questionnaire were developed. After taking into consideration specific South African differences and the views of environmental health specialists regarding the present problems in the management of medical waste and the expected results from the questionnaire, some modifications were made to the questionnaire suggested by the WHO. The site visits were very helpful in obtaining information about the common practices in the management of the wastes.

The results obtained were discussed to ascertain the extent to which medical wastes are handled in the light of written policies and the established international standards in this regard (WHO, 1999).

3.3 Validity and Reliability

Validity refers to the degree to which a test or an instrument measures or performs the task it is meant for. Reliability, on the other hand, refers to the replicability or the reproducibility of the instrument, that is, if it is consistently replicable. The validity and reliability of the instruments of this study was ascertained by following the recommendations of World Health Organisation.

3.4 Ethical Consideration

The hospital and the respondents were made aware of the fact that the research is purely an academic requirement and as such information gathered will be treated with strict confidentiality.

3.5 Data Analysis

The analysis is essentially descriptive. Data for the analysis was extracted from questionnaire and personal interviews carried out by the researcher.

3.6 Limitations of the Study

The researcher had some constraints, with respect to the information received, in that some relevant information was not provided by respondents due to the sensitive nature of the topic. However, these limitations did not affect the findings of the research.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter includes a discussion of the results of the study. It begins by providing a profile of the Tygerberg Hospital. It then discusses the medical waste management practices, the waste management policies and the problems involved in managing medicate wastes at the Tygerberg Hospital.

4.1 Profile of Tygerberg Hospital

Tygerberg Hospital, which is the leading health facility in the Western Cape for trauma and other acute cases, was built during the time of apartheid. It was officially opened in 1976. Originally one half of the hospital housed "white patients" and the other half "non-whites". Since 1994, and with the end of the apartheid regime, large parts of the hospital's building have been left idle. The vast majority of patients using this state facility are "non-whites", with only a handful of "white patients" attending for specialists' outpatient services. Most wealthy people attend private hospitals. The hospital was designed for 1,899 beds, but presently has 1,278 beds, including 300 beds for Tygerberg children's hospital, day surgery unit and private patients units. The hospital has about 50 wards, 28 theatres and 30 out patient departments. The profile of the hospital is indicated in Table 4.1.

Tygerberg Hospital, which serve as the teaching hospital for Stellenbosch University has a staff strength of about 4,000 and an annual budget of R770,000,000. The hospital has as its mission the provision of affordable world class quality healthcare to public and private patients within available resources, as well as excellent educational and research opportunities. The hospital caters for all specialities appropriate to a large academic hospital, such as general surgery and sub-disciplines, example orthopaedics, and ophthalmology, internal medicine and sub-disciplines, e.g. cardiology and nephrology, as well as obstetrics and gynaecology. Over 2 million people receive healthcare from Tygerberg Hospital either directly or through its secondary hospitals, such as Karl Bremer, Paarl and Eben Donges (Worcester).

Table 4.1: Profile of Tygerberg Hospital

Details	Hospital Charateristics
Year of Establishment	1976
Number of Beds	1,278
Number of Wards	50
Number of Theatres	28
Out patients Departments	30
Number of Staff	4,000
Annual Budet	R770,000,000
Location	Western Cape
Hospital Type	Teaching Hospital

Tygerberg Hospital plays a central role in the delivery of tertiary services and secondary services in the Western Cape. The hospital makes significant contribution to teaching and training of health professionals as well as research in partnership primarily with the Stellenbosch University and also University of Western Cape, Cape Peninsula University of Technology and the Western Cape College of Nursing.

4.2 Medical Waste Management Practices

4.2.1 Waste Production

Waste is generated from the various activities performed in the hospital. Wastes produced in the hospital include general and medical wastes. General waste produced at the hospital is related to food preparation, administrative activities, and landscaping. This type of waste is similar to household and city wastes. In the Tygerberg Hospital, different kinds of therapeutic procedures such as cobalt therapy, chemotherapy, dialysis, surgery, delivery, resection of gangrenous organs, autopsy, biopsy, para-clinical exams, and injections, among others, are carried out and result in the production of infectious wastes, contaminated sharps with patients' blood and secretions, radioactive wastes and chemical materials which are considered to be hazardous wastes (Prüss *et al.*, 1999). The amount of waste generated in hospitals depends upon various factors such as number of beds, types of health services provided, economic, social and cultural status of the patients and the general condition of the area where the hospital is situated. For example, in hospitals located in low socioeconomic areas of the cities, most of the waste consists of residues from fruits which are voluminous and abundant, whereas in those located in high socioeconomic areas of the city; most of wastes contain flowers, cans and single use containers for food (Askarian *et al*, 2004). However, during our interview with waste management staff in the hospital, they could not tell the amount of waste generated in the hospital daily. They could not also provide information with respect to which departments generate the highest and lowest amounts of medical waste in the hospital.

4.2.2 Waste Segregation

The hospital basically separates medical waste from general waste stream at the waste production points. Therefore, they are stored and disposed of separately. However, the hospital does not segregate medical wastes into different categories. In the wards, doctors and nurses who use sharps are required to drop them into different containers but this is not diligently followed. Users of sharps sometimes leave them on hospital beds and this could be very dangerous to patients. According to the proposal by WHO, hospitals have to provide plastic bags and strong plastic containers for infectious waste such as empty containers of antiseptics used in the hospital. Bags and containers for infectious waste should be marked with Biohazard symbol (Prüss *et al.*, 1999). During our interview it was revealed that segregation of medical wastes into infectious medical waste and non-infectious medical waste is not conducted according to definite rules and standards. The hospital does not label infectious waste with Biohazard symbol. No control measures exist for the management of these wastes. Separation of medical waste and general waste is however practiced to a satisfactory extent.

4.2.3 On-site Transport of Medical Waste

Medical wastes generated in the hospital are on a daily basis collected and transported to a temporary storage area by hospital's staff. It is imperative for medical waste to be transported within the hospital by means of wheeled trolleys, containers or carts that are not used for any other purpose. In Tygerberg Hospital, wheeled trolleys are used for on-site transport of waste from the sites of production (different wards) to the temporary storage area. The staff employed for handling waste in the hospital use almost complete personal protective equipment, including overall gown and protective boots and gloves. It is important to note that the lack of suitable and sufficient protective equipment, the lack of knowledge regarding the correct usage of equipment and the lack of pertinent understanding of the personnel regarding the benefits of using protective equipment exposes personnel to serious dangers. The hospital does not maintain a record or register for medical waste disposal.

4.2.4 Temporary Storage

The place where the hospital waste is kept before transporting to the final disposal site is termed as a temporary waste storage area. This area must be well sanitised and secured in such a way that it should be accessible only to authorised persons (Prüss *et al.*, 1999). Tygerberg Hospital has a well secured but poorly sanitised temporary storage area. The wastes are kept in this temporary storage area until it is time for off-site transport. The infectious and non-infectious wastes are kept in the hospital's own temporary storage area. On the whole, the hospital maintains three collection points for medical wastes.

4.2.5 Medical Waste Treatment

Waste treatment leads to a decrease in volume, weight, and risk of infectivity and organic compounds of the waste (Prüss *et al.*, 1999). During the interview, it was indicated to the researcher that Tygerberg Hospital outsources its waste management function to a waste management company. Incineration is the main method for the treatment of medical waste especially infectious and sharp wastes for the hospital. Autoclaves are used for treating part of the wastes.

4.2.6 Off-site Transport of Medical Waste

Off-site transport of the hospital waste is undertaken by a waste management company and waste is transported daily. Small pickups are mainly used by the waste management company for off-site transportation of waste. Johannessen *et al* (2000) recommend that transportation of medical waste on public roads must be carried out by trained staff in a dedicated vehicle with closed containers. However, the wastes are loaded directly into the pickup without putting them first into closed containers. Given the small size of the pickups, the wastes are usually heaped and they fall off on the roads during transportation. The hospital's staffs are not involved in this function and therefore there is no supervision from the hospital. There are instances where wastes that fall off the pickup during loading at the hospital's premises are unattended to. This poses a serious health risk as well as a nuisance to workers and patients. Table 4.2 indicates that the Tygerberg Hospital outsources its off-site transportation of medical waste.

Table 4.2: Method of Transporting Medical Waste

Method	Response
By Hospital	No
Outsouced to Private Firm	Yes

4.2.7 *Final Disposal of Medical Waste*

Diaz *et al* (2005) identified some of the more common treatment and disposal methods utilised in the management of infectious medical wastes in developing countries to include autoclaves and retorts; microwave disinfection systems; chemical disinfections; combustion (incineration); and disposal on land (dump site, controlled landfill, pits and sanitary landfill). The final disposal of the medical waste is done by the private waste management company. The main treatment method used in the final disposal of infectious waste is incineration. This is illustrated in Table 4.3. Wastes from hospitals are transported to an off-site area, which has been dedicated for this purpose. Non-infectious waste as indicated in Table 4.4 is disposed of using land disposal method. The final disposal site for medical wastes is accessible only by authorised persons. Recycling of the medical waste is not practiced in the hospital except white office paper and mixed office paper and the use of empty containers of antiseptics for the collection and temporary storage of sharps. The hospital during the time of the study did not have a subcommittee to monitor how the final disposal of the medical waste is done. Everything is left at the care of the private waste management company.

Table 4.3: Method of Treating and Disposal Infectious Medical Waste

Method	Response
Infectious Waste:	
Auto Clave	N
Incineration.	Y
Microwave disinfection system	N
Chemical disinfection	N
Combustion	N
Land disposal	N
Burial.	N
Deep Burial	N
Burning.	N

N means does not use the method
Y means uses the method

Table 4.4: Method of Treating and Disposal Non-Infectious Waste

Method	Response
Infectious Waste:	
Auto Clave	N
Incineration.	N
Microwave disinfection system	N
Chemical disinfection	N
Combustion	N
Land disposal	Y
Burial.	N
Deep Burial	N
Burning.	N

N means does not use the method
Y means uses the method

It was also revealed during the interview that the hospital does not have a programme in place for eliminating the use of mercury-containing products. There is also no programme in place to reduce, minimise the purchase and use of PVC (#3) plastic packaging and containers.

4.2.8 Medical Staff

The waste management function at the hospital is under the general services department with a supervisor who reports to the Deputy Director of Administration. The general services department is also in charge of security, reprographics, typists, archives and messengers, transport, gardens, cleaning, pest control, lift operators, pneumatic tube exchange, telephone exchange, porters and mortuary. There is also a nurse in charge of medical waste at the ward level who reports to the head of infection control department, who is an expert in public health. Staff in charge of the medical waste do not have any qualification in medical waste management. The supervisor has attended a short course on healthcare waste management, organised by Technology Services International. This was a two day course of 8 hours each day.

The interview indicated that training was not provided to doctors and other personnel about medical waste management and their potential hazards. Newly hired waste management staffs are not given any form of training. Staff members are also not given training on the health and environmental effects of infectious waste annually. The private waste management company's workers, who are responsible for the off-site transportation of medical waste to the final disposal site, are not cautioned about the hazards associated with medical waste. The waste management company's workers have also not received any formal training with regard to medical waste management, and are consequently unaware of the environmental health impacts of medical waste. Lack of proper training in the hospital with respect to waste management poses serious risks to the personnel as far as the hazards of hospital waste is concerned. The process of collection, segregation, and disposal of hospital waste are not performed according to WHO's recommended standards, hence patients, visitors, society and the entire environment are exposed to the dangers of such waste.

In developed countries, training programmes and educational classes are instituted repeatedly for all personnel and the content of these programmes are specifically designed for different personnel. In the USA, part 1910, 1030 are related to Occupational Health and Welfare (29 CFR part 1910, 1030 OSHA) and regulates the training needs for different personnel who are employed in centres where hospital waste production occurs (Department of Environmental Conservation, New York State, 1996).

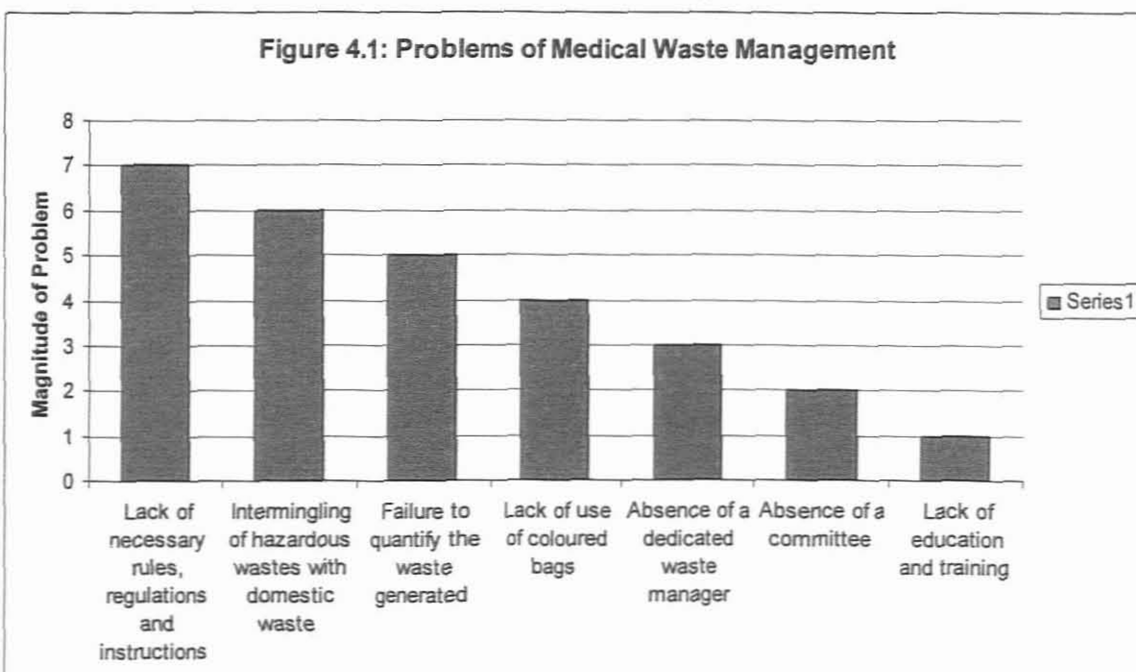
4.3 Medical Waste Management Policies and Regulations

There is no clear policy and plan in place for managing medical waste at the Tygerberg Hospital. There is no definite policy or plan for purchasing the necessary equipment and for providing the facilities for the correct management of medical waste in the hospital. The hospital has a medical waste management guideline prepared by the head of infection control but this is not strictly followed. There are still areas where medical wastes are not managed properly at the hospital. For instance, there is no segregation of waste, particularly sharps. The hospital does not have a regular report about how medical waste management is practiced and the process of performing respective studies is also not reported. On the contrary, in developed countries, definite rules and regulations exist at the national, regional and hospital levels. For example, in the University Hospital of Freiburg, Germany, there are almost 36 rules at the national level, five rules at the regional level, and 13 rules at hospital level, resulting in a total of 54 rules for the correct management of hospital waste (Daschner, 2000). The interview however revealed that Tygerberg Hospital in the last three years has carried out a waste management audit.

There are however no policies and guidelines regarding the recycling of medical waste products.

4.4 Problems of Medical Waste Management

During an interview with the head of infection control unit and the supervisor in charge of general services, it was revealed that the hospital currently has a number of problems in managing its medical waste. The main problems and their magnitute are presented in Figure 4.1.



The main problems facing the hospital in terms of medical waste management include:

- Lack of necessary rules, regulations and instructions on the different aspects of collection and disposal of waste.

- Intermingling of hazardous wastes with domestic waste in the hospital sometimes.
- Failure to quantify the waste generated in reliable records.
- Lack of use of coloured bags thereby limiting the bags to only one colour for all waste.
- The absence of a dedicated waste manager. The supervisor in charge of general services has waste management as part of his job schedule.
- The absence of a committee responsible for monitoring medical waste management practices.
- Lack of education and training on medical waste management.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

In this final chapter, the important points emerging from the results of the study are summarised. Conclusions from the study are based on the findings of the study. Valid suggestions and recommendations in line with the objectives of the thesis have been made. This chapter also provides directions for future research in the area.

5.1 Summary

This study examined the medical waste management practices of Tygerberg Hospital. The specific objectives of the study were to: 1) report on the current status of regulations and practices regarding medical waste procedures at the Tygerberg Hospital, 2) indicate mismanagement practices at the Tygerberg Hospital, 3) investigate what problems the hospital encounters in managing medical wastes, and 4) make relevant recommendations aimed at improving the waste management system in the Tygerberg Hospital in particular and South African hospitals in general.

The researcher made frequent visits to the hospital, taking note of how medical waste is managed. Regular visits were made to general medical wards, maternity wards, surgical and critical care wards, operating theatres, and orthopaedic sections. The researcher also made use of both primary and secondary data. Secondary data was obtained from the hospital's documents. Information was also obtained from published and unpublished books, journals, newsletters, periodicals, articles and the Internet. Primary data was collected from questionnaire administration and interviews with authorities of the hospital, health workers and personnel in charge of infection control and waste management at the hospital. Since this was a case study, the analysis was essentially descriptive. The discussions were based on what exist in the hospital in terms of medical waste management vis a vis recommended practice.

The study revealed that both general and medical wastes are generated in the hospital. Medical waste is generated from medical practice such as therapeutic procedures like cobalt therapy, chemotherapy, dialysis, surgery, delivery, resection of gangrenous organs, autopsy, biopsy, para-clinical exams, and injections among others. Tygerberg Hospital does not quantify medical waste, as we could not obtain information on the amount of waste generated in the hospital daily. They could also not tell which departments generate the highest and lowest amounts of medical waste in the hospital. Segregation of medical wastes into infectious medical waste and non-infectious medical waste is not conducted according to definite rules and standards. The hospital does not label infectious waste with Biohazard symbol. Separation of medical waste and general waste is practiced to a satisfactory extent though. Wheeled trolleys are used for on-site transport of waste from the sites of production (different wards) to the temporary storage area. The staff employed for handling waste in the hospital use almost complete personal protective equipment, such as overall gowns, protective boots and gloves.

The results of this study indicated that off-site transport of the hospital waste is undertaken by a private waste management company, which transports waste daily. Small pickups are mainly used by the waste management company for transporting the waste to an off-site area for treatment and disposal. The final disposal of the medical waste is thus the responsibility of the private waste management company. The main treatment method used in the final disposal of infectious waste is incineration. Non-infectious waste is disposed of using land disposal method. The hospital does not recycle medical waste materials except white office paper and mixed office paper and the use of empty containers of antiseptics for the collection and temporary storage of sharps.

The hospital does not provide training for doctors and other personnel about medical waste management and their potential hazards. Newly hired waste management staff are not given any form of training. Staff members are also not given training on the health and environmental effects of infectious waste annually. The waste management company's workers have also not receive any formal training with regards to medical waste management and are consequently unaware of the environmental health impacts of medical waste.

The study showed that Tygerberg Hospital does not have any policy and plan in place for managing medical waste. There is no definite policy or plan for purchasing the necessary equipment and for providing the facilities for the correct management of medical waste in the hospital. There are also no policies and guidelines regarding the recycling of medical waste products. The main problems confronting the hospital with respect to the management of medical waste include: lack of necessary rules, regulations and instructions on the different aspects of collection and disposal of waste, intermingling of hazardous wastes with domestic waste of the hospital sometimes, failure to quantify the waste generated in reliable records, lack of use of coloured bags thereby limiting the bags to only one colour for all waste, the absence of a dedicated waste manager, the supervisor in charge of general services has waste management as part of his job schedule, the absence of a committee responsible for monitoring medical waste management practices, and the lack of education and training on medical waste management.

5.2 Conclusion

Medical waste must be separated from municipal waste, but in many parts of Africa it tends to be collected along with the rest of the waste stream. Poor management of medical waste has serious health implication to health workers, patients and the public. Also, due to the toxic nature of medical waste, improper handling may lead to the destruction of natural environment and disturb the balance of the ecosystem. This study examined the medical waste management practices in one major hospital in South Africa, the Tygerberg Hospital. From the results of the study, it is obvious that medical waste management is not practiced according to WHO's recommended standards. There are some areas where medical wastes are not properly managed. It is imperative for significant investment in the proper management of medical waste in order to reduce the health risk it poses. The researcher hopes that this study will create the awareness regarding the problem of medical waste management in hospitals and will generate interest for systematic control efforts for effective medical waste management.

5.3 Recommendations

In the light of the above observations made, a number of recommendations are hereby made with the hope of improving the management of medical waste in South African hospitals in general and Tygerberg Hospital in particular. The following recommendations could enhance the operating efficiency of the hospital with regards to medical waste management:

- It is important to measure and quantify the amount of medical waste generated in each unit of the hospital periodically to ascertain which unit or department generates the highest and lowest amount of wastes. This could have implications for resource allocation in managing medical waste.
- There is the need for proper segregation of infectious medical waste and non-infectious medical waste. The provision of plastic bags and strong plastic containers for infectious waste such as empty containers of antiseptics used in the hospital is necessary. Bags and containers for infectious waste should be marked with Biohazard symbol. A standardised system of red colour coded bags used for the segregation of risky waste should be used and rigidly followed. Imposition of segregation practices within the hospital will result in a clean waste stream which can be easily, safely and cost-effectively managed.

- The hospital should institute an efficient Sharps Management System, including proper equipment and containers at all sharps generating points, a secure accounting and collection system for transporting the contaminated sharps for treatment and final disposal as well as the proper training of hospital staff on the handling and management of sharps.
- The hospital should institute regular training and education of all workers, from doctors to ward boys, laborers, rag pickers and also workers of the private waste management company. Proper training is necessary to develop awareness of health, safety and environmental issues. It is important for workers to know and understand the potential risks associated with healthcare wastes.
- Medical waste should be transported in suitable dedicated wheeled leak-proof containers. They should be clearly marked and regularly cleaned. The waste should be carried in a special purpose vehicle or in a special leak-proof, lidded container.
- Environmental health experts must be included in the Infection Control team in the hospital, as well as some waste management experts. This will improve the ability and effectiveness of the Infection Control team to carry out its operations.
- There must be a separate department for dealing with medical waste and another for domestic waste. This may increase the efficiency of medical waste management.
- The hospital should develop clear plans and policies for proper management and disposal of medical wastes. It is important to formulate a medical waste management policy separately from the hospital's waste management system.

This should be done by a multidisciplinary team including environmental health specialists.

- The hospital must set up a sub-committee to be responsible for medical waste management in the hospital. The sub-committee should be in charge of periodic reviewing and resolving medical waste management issues in the hospital. The sub-committee should also monitor closely the activities of the private waste management company to ensure that they perform their duties as expected.

5.4 Directions for Future Research

Following from the findings of the study, it would be useful to also consider the following directions for future research:

- The medical waste management practices of public and private hospitals in South Africa;
- The health effects of medical waste disposal in South Africa;

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APPENDIX I

<u>Questionnaire</u>

<u>Medical Waste Management at Tygerberg Hospital in the Western Cape,</u>

<u>South Africa</u>

General

1. Hospital organisational structure

2. How many departments do you have?.......................

3. How many patients bed does the hospital have?.........................

4. Any general material on Tygerberg Hospitals

Medical Waste Management Policy

5. Are you aware of a document outlining the hospital waste management policy?

   Yes ( )   No ( )

6. If YES, give title of document (and attach a copy if possible):................

7. Are you aware of any legislation applicable to the hospital waste management?

Yes ( ) No ( )

8. If YES, please list the legislative Act

....

....

9. Is there a manual or guideline document on management of hospital wastes available in the Ministry of Health?

Yes ( ) No ( )

10. If YES, give title of document

....

11. Does the hospital have a waste management plan?

Yes ( ) No ( )

12. Does your hospital have a Waste Management Team (or Teams)?

Yes ( ) No ( )

13. If YES, please list the members by designation:

Designation/Position

Team leader: ....

Team member: ....

Waste handling staff: ....

14. Is there a manual or guideline document on management of hospital wastes available at the Tygerberg Hospital?

Yes ( )   No ( )

15. If YES, give title of document

....

16. Are there waste management responsibilities included in the job descriptions of hospital supervisory staff (Head of hospital, Department Heads, Nursing superintendent, Pharmacist, Lab Supervisor etc)?

Yes ( )   No ( )

17. How are the present waste collection, handling, and disposal responsibilities defined in the job descriptions of the staff involved? (Cite appropriate statement or provide copies.)

....

....

....

....

....

18. Does your hospital have guidelines that specify a purchasing preference for products in minimal packaging or in packaging that is recyclable or made from recycled materials?

Yes ( ) No ( )

19. Does your hospital have a policy that promotes the use of reusable products rather than single use, disposable products where feasible?

Yes ( ) No ( )

20. Does your hospital have a policy that promotes the use of office paper that is

A) Chlorine-free?

B) Greater than 20% recycled content?

C) Both?

D) Neither?

21. Does your hospital have a policy that promotes the purchasing of unbleached, processed chlorine-free or totally chlorine-free sanitary napkins, napkins, paper towels and toilet paper?

A) Yes, for three or four of the products

B) Yes, for one or two of the products

C) No

Medical Waste Management Practices

22. What is the quantity of waste generated every day in the hospital?……………………………………………….

23. Which department records the highest amount of medical waste?

………………………………………………………………

24. Which department records the lowest amount of medical waste?

………………………………………………………………

25. Are there clearly defined procedures for collection and handling of wastes from specified units in the hospital?

Yes ( ) No ( )

26. Are medical wastes segregated into different categories?

Yes ( ) No ( )

27. If YES, who does the segregation
   a) Doctor
   b) Nursing Assistant
   c) Auxillary staff
   d) Do not Know

28. Does your waste management process involve the following:

- Identification of waste type
- Separation of non-infectious or general waste from infectious waste
- Packaging
- Transferring all waste bags on wheeled containers and using utility gloves when dealing with broken bags and waste and then decontaminating them

Yes ( ) No ( )

29. Do you colour code the medical waste for disposal?

Yes ( ) No ( )

30. How do you transport waste on-site?..

31. How do you transport waste off-site?..

32. Tick the facilities available for waste management.

a) Auto Clave
b) Incineration.
c) Microwave disinfection system
d) Chemical disinfection
e) Combustion
f) Land disposal
g) Burial.

h) Deep Burial

i) Burning.

33. How do you dispose of non-infectious waste?

....

....

....

34. How do you dispose of infectious waste?

....

....

....

35. Is the infection waste labelled with the Bio-Hazard Symbol?

Yes ( ) No ( )

36. What is your hospital's current method for the treatment and disposal of regulated medical waste?

On site:

A) Autoclave

B) Incineration

C) Other (please explain) ....

Off site:

A) Autoclave

B) Incineration

C) Other (please explain) ....

Combination:

A) On-site:...

B) Off-site:...

37. Do you have disposal subcommittees in different departments to monitor disposal of medical waste?

Yes ( )   No ( )

38. What is the educational background of staff in charge of medical waste management at the hospital?

....

39. In light of the new medical waste incinerator regulations (August 1997) are you in the process of re-evaluating how to handle your hospital's regulated medical waste?

Yes ( )   No ( )

40. If YES, what options are you considering?

A) Upgrading incinerator with new pollution controls

B) Shutting down incinerator

C) Contracting for off site services

D) Exploring alternative technologies for on site treatment and disposal

E) Other (please explain) ....

41. Has your hospital done a waste audit in the last three years?

Yes ( ) No ( )

42. Do you maintain a register for waste disposal?

Yes ( ) No ( )

43. Please circle the items your hospital currently collects for recycling.

A) White office paper

B) Mixed office paper

C) Corrugated cardboard

D) Boxboard

E) Newspaper

F) Magazines

G) Books

H) Junk Mail

I) Aluminum

J) Steel Cans

K) Glass

L) Plastics (circle types)

#1 PET

#2 HDPE

#3 PVC

#4 LDPE

#5 PP

#6 PS

#7 Mixed

M) Batteries (circle types that are recycled)

1. Ni-cad
2. Mercuric oxide
3. Alkaline
4. Lead acid
5. Zinc air
6. Lithium
7. Dry cell
8. Others

N) Toner cartridges

O) Overhead transparency film

P) Fluorescent lights

Q) Silver (x-ray film and solution)

R) Formatin

S) Xylene

44. Does your hospital have a programme in place to eliminate the use of mercury-containing products?

Yes ( )   No ( )

45. Does your hospital have a programme in place to reduce PVC (#3) plastic packaging and containers?

Yes ( )   No ( )

46. Does your hospital have a programme in place to minimise the purchasing of PVC (#3) products?

Yes ( )   No ( )

47. Does your hospital use PVC (#3) plastic IV bags?

A) Yes

B) No

C) Unsure

48. Are there acts of mismanagement of medical wastes?

Yes ( )   No ( )

49. If YES, what are they ………………………………………..

Employee Education

50. Do you train newly hired waste management staff?

Yes ( )   No ( )

51. Are staff members given annual training on the health and environmental effects of mercury?

A) Yes

B) No

C) Included in hazard communication programme

52. Does your hospital provide employee training on how to properly clean up a mercury spill?

A) Yes

B) No

C) Only to designated personnel

53. Does your hospital provide annual education on waste management for employees?

Yes ( )   No ( )

54. If YES, does that education include information on waste segregation including proper identification and disposal of red bagged or infectious waste?

Yes ( ) No ( )

55. What problems do you encounter in managing medical waste at the Tygerberg Hospital?

a. Lack of definite policies and budget allocation at the provincial and hospital level regarding hospital waste management.
b. Lack of necessary rules, regulations and instructions on different aspects of collection and disposal of waste.
c. Lack of proper training for different personnel of the hospitals, especially the staff responsible for hospital waste management regarding the hazards and correct management of hospital waste.
d. Intermingling of hazardous wastes with the domestic waste of the hospitals.
e. Lack of incinerators or low quality of operation and improper treatment of hazardous hospital waste.
f. Lack of control and supervision on the collection and disposal of hospital waste.
g. Lack of suitable and adequate protective equipment in hospitals.
h. Pouring of liquid chemical waste into the city sewerage system without any prior treatment.
i. Failure to quantify the waste generated in reliable records

j. Lack of use of coloured bags by limiting the bags to only one colour for all waste

k. Staff in charge of medical waste

l. Others, please explain ....

56. What do you think in your opinion can be done to improve the medical waste management at the Tygerberg Hospital?

....

....

....