

An Assessment of Medical Waste Management
Practices In the North-eastern Free State,
South Africa

Pululu Sexton Mahasa

An Assessment of Medical Waste Management Practices in the North-eastern Free State, South Africa



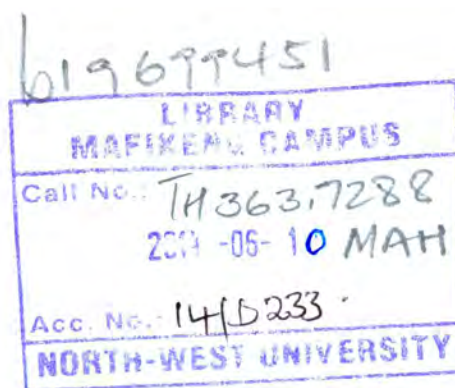
060043291P

North-West University
Mafikeng Campus Library

Pululu Sexton Mahasa

Dissertation submitted for the degree of Master of Science (Environmental Science),
Mafikeng Campus of the North-West University

Supervisor: Prof Tabukeli Musigi Ruhiiga



June 2013

DECLARATION

I declare that the dissertation hereby submitted for the degree (Master of Science - Environmental Science at the North West University (Mafikeng Campus) is my own original work and has not previously been submitted by me at another university/faculty. I further more cede that copyright of the dissertation in favour of the North West University (Mafikeng Campus).

Signed:

.....

Pululu Sexton Mahasa

ABSTRACT

The proper handling and disposal of medical waste in accordance with national guidelines is very important. This study was undertaken to investigate the state of medical waste and management practices in different hospitals in the north-eastern Free State Province, South Africa. A random sample of ten (10) hospitals was selected. Observation of operations was carried over a period of six months. A stratified random sample of 138 staff members spread across the ten medical facilities was selected and face-to-face interviews were conducted. The hospitals were grouped into 3 categories namely large, medium and small in terms of the number of hospital beds. Data collection through observation and interviews covered waste generation, storage, handling, transportation, treatment and management procedures. Data analysis made use of SPSS to generate descriptive statistics, correlation coefficients and t-tests in hypothesis testing. The findings reveal that medical personnel do not treat medical waste as specified in official guidelines, there is no formal training for personnel, medical waste is not a key priority, there are low levels of environmental awareness, inappropriate treatment of waste at some sites, and inadequate budget allocations for medical waste management. These findings indicate that there is an urgent need for addressing issues of awareness for managers, better on-the job training for personnel, better systems for on-ward conveyance of waste from facilities to official medical waste treatment plants, an up-grade of existing incinerators and a consistent schedule of data capture should be implemented.

Key words: hazardous waste, incineration, waste generation, waste segregation, waste treatment.

ACKNOWLEDGEMENTS

I would like to express my heartfelt thanks to everybody who contributed to the successful completion of this study, especially the following:

- First, I wish to thank my supervisor, Prof. Tabukeli Musigi Ruhiiga for providing me a place in the department as well as for encouraging me to do my MSc in this topic. His friendship, excellent guidance, inspiration, close monitoring, constructive criticism, kind approach, patience, understanding and hospitality through all stages of my research are gratefully acknowledged, for which I remain indebted.
- An enormous debt of gratitude goes to my wife, Limpho Patricia 'Maphole and children (Mofuli Kish, Thato Augustina, Relebohile Priscilla, Morareli Gabriel and Phole Simon) for their love, patience and constant inspiration, unfailing encouragement and the many hours sacrificed without a husband's and father's company and attention throughout the period of my study. They are sources of my strength and motivation.
- I would like to express my sincere appreciation to my parents, parents-in-law, aunts, sisters and friends, for their continued moral support, love, encouragement, understanding, sacrifice, and endless prayers for my success throughout my study.
- I specially would like to convey my deepest and sincere gratitude to Cde Ntene, Cde Matsie and Mme Tlaleng, who kindly assisted me during the research /field work and provided the usual unfailing encouragements through their kind personalities.
- I would like to extend my thanks and appreciation to all the staff at the Departments of Geography (i.e. NWU – Mafikeng & UFS - Qwaqwa Campuses) for their outstanding technical support and assistance, research input, advice and friendship.
- Finally, my thanks to Almighty God, from Whom all blessing flow and Who gave me strength to complete this study.

DEDICATION

This work is dedicated to my wife Limpho Patricia 'Maphole, my children - Mofuli Kish, Thato Augustina, Relebohile Priscilla, Morareli Gabriel, Phole Simon, the Mahasa Family, relatives and friends.

STATEMENT OF PERMISSION TO COPY

In presenting this research study, in accordance with the requirements for the Master of Science (Environmental Science) degree at the North-West University (Mafikeng Campus), I agree that the Library shall make it freely available for inspection. I further agree that my supervisor/department may grant permission for extensive copying of this research study for scholarly purposes. It is understood that any copying or publication of this study for financial gain shall not be allowed without my written permission.

.....
Signature

JUNE 2013

Date

TABLE OF CONTENTS

DECLARATION	ii
ABSTRACT	iii
ACKNOWLEDGEMENTS	iv
DEDICATION	v
STATEMENT OF PERMISSION TO COPY	vi
TABLE OF CONTENTS	vii
ABBREVIATIONS	xi
LIST OF FIGURES	xii
LIST OF TABLES	xiv
LIST OF PHOTOGRAPHS	xv
CHAPTER 1 BACKGROUND TO THE STUDY	1
1.1 Introduction	1
1.2 Problem Statement	3
1.3 Research Purpose	4
1.4 Research Objectives	4
1.5 Research Hypothesis	4
1.6 Significance of the Study	5
1.7 Definition of Concepts	5
1.8 Structure of the Study	6
1.9 Summary	8
CHAPTER 2 LITERATURE REVIEW	9
2.1 Introduction	9
2.2 Medical Waste	9
2.3 E-waste and PCBs.....	11

2.4 Medical Waste Management	13
2.5 State of Technologies	16
2.6 Chemical Treatment	18
2.7 Sterilization	18
2.8 Microwave Technology	21
2.9 Plasma Arc Technology	22
2.10 Steam-based Treatment.....	23
2.11 Electro Thermal Deactivation (ETD)	24
2.12 Effects of Medical Waste on Public Health	25
2.13 Risk of Medical Waste to the Environment	33
2.14 Risk of Medical Waste to People and Animals	35
2.15 Medical Waste Treatment in South Africa	36
2.16 System Indicators and Indexes	39
2.17 Summary	43
 CHAPTER 3 METHODS AND MATERIALS	 45
3.1 Introduction	45
3.2 The Study Area	45
3.3 Research Design	47
3.4 Choice of Instruments	47
3.5 Validity	49
3.6 Population	49
3.7 Unit of Analysis	50
3.8 Specification of Variables	50
3.9 Sampling Procedures	50
3.10 Data Collection and Analysis	53

3.10.1 State of Operational Procedures	53
3.10.2 Elements of Medical Waste Chain	54
3.10.3 Quantifying Standards for Handling Medical Waste	55
3.10.4 Identification of the Critical Technical and Managerial Limitations	55
3.11 Ethical Considerations	57
3.12 Summary	59
CHAPTER 4 RESULTS AND ANALYSIS.....	60
4.1 Introduction	60
4.2 Status of Current Medical Waste Management Practices.....	60
4.3 Analysis of Medical Waste Management Chain	68
4.4 Operating Standards	73
4.5 Limitations in Waste Management Handling	75
4.6 Hypothesis Testing.....	78
4.7 Summary	80
CHAPTER 5 DISCUSSIONS	82
5.1 Introduction	82
5.2 Current Medical Waste Management Practices	82
5.3 Medical Waste Management Chain.....	83
5.4 Operational Practices.....	83
5.5 Managerial and Technical Limitations.....	84
5.6 Summary	89
CHAPTER 6 CONCLUSION AND RECOMMENDATIONS	90
6.1 Introduction	90

6.2 Conclusion.....	90
6.3 Recommendations.....	91
REFERENCES	93
APPENDICES	113
Appendix A (Interview).....	113
Appendix B (Observation).....	117
Appendix C (Letter of Introduction – HOD [FS – Health])	118
Appendix D (Request to the Head of Health)	119
Appendix E (Consent Letter for Participation)	120
Appendix F (Content of Hazardous Medical Waste Survey Interviews)	121
Appendix G Geography by Population group and Sex.....	122
Appendix H Geography by Attending school (Institution)	123
Appendix I Geography by Language	124

ABBREVIATIONS

DEAT:	Department of Environmental Affairs and Tourism
DOH:	Department of Health
FAST:	Faculty of Agriculture, Science and Technology
MRC:	Medical Research Council of South Africa
NWU:	North West University
RSA:	Republic of South Africa
UNICEF:	United Nations Cultural and Education Fund
USAID:	United States Agency for International Development Aid
WHO:	World Health Organisation

LIST OF FIGURES

Figure 1 Structures of Selected Chlorinated, Brominated and Fluorinated POPs or PCBs Precursors	12
Figure 2 Substance Flow of POPs/Persistent Toxic Substances and Human Exposure and the Important Role of Landfills, Stockpiles and Contaminated sites, Soils and Sediments for the POPs Life Cycle	13
Figure 3 Proposed National Medical Waste Chain	37
Figure 4 Medical Waste Chain in the Study Area	38
Figure 5 The Map of Free State, South Africa	46
Figure 6 Flow-line of the Design	48
Figure 7 Respondents per Level of Medical Facility	60
Figure 8 Segregation Duties per Level of Medical Facility	62
Figure 9 Appropriate Colour-coding Levels of Respondents	62
Figure 10 Respondents' Method of Medical Waste Disposal	63
Figure 11 Appropriate Colour-coding and Disposal Mode per Facility	64
Figure 12 Waste Management Practice and Disposal Mode per Facility	65
Figure 13 Waste Collection and Disposal Mode per Facility	65
Figure 14 Health Settings and Waste Management Policy	67
Figure 15 Health settings and Waste Management Chain	67
Figure 16 Health settings and Colour – coding Practice	68
Figure 17 The Flow Diagram of Medical Waste at the Regional Level Hospitals	72
Figure 18 The Flow Diagram of Medical Waste at the District Level Hospitals	72
Figure 19 The Flow Diagram of Medical Waste at Specialised and Other Hospitals	73
Figure 20 Levels of Education and Waste Management Policy	76
Figure 21 Individual Attitude Assessments towards Waste Management	77

Figure 22 Levels of Attitude Assessment towards Waste Management.....	78
Figure 23 Levels of Attitude Assessment towards Waste Management (Cont'd)	79

LIST OF TABLES

Table 1 Classification of the Different Types of Medical Solid Waste.....	10
Table 2 Medical Waste Categories and Description	11
Table 3 Hazardous Medical Waste Treatment Technologies	26
Table 4 Examples of Different Pathogens and Diseases caused by them	32
Table 5 Medical Facilities	45
Table 6 Variables	51
Table 7 Allocation of Interviews for Participants	53
Table 8 Distributions of Interviews	54
Table 9 Health Settings and Waste Management Policy	66
Table 10 Statistics - Average Rates	74
Table 11 One sample T-Test: Average Rates compared to Standardised Rates	74
Table 12 Confidence Interval of the Difference.....	75
Table 13 Correlation Coefficients	80

LIST OF PHOTOGRAGHS

Photograph 1 Intermingled Medical Waste	69
Photograph 2 Inappropriate Uses of Plastic Containers	70
Photograph 3 An Overfilled Temporary Medical Waste Storage Facility.....	70
Photograph 4 An Unlocked Temporary Medical Waste Storage Facility showing Sharps'	
Containers.....	71

Department of Geography and Environmental Science
School of Environmental and Health Sciences
Faculty of Agriculture, Science and Technology

June 4, 2013

TO WHOM IT MAY CONCERN

Dear Sir or Madam,

Re: **MSc Dissertation Language Editing: Mr Pululu Sexton Mahasa**

I, the undersigned, have edited the following MSc dissertation by Pululu Sexton Mahasa for language correctness:

"An Assessment of Medical Waste Management Practices in the North-eastern Free State, South Africa".

The candidate has undertaken the necessary corrections to errors identified. I, therefore, certify that the dissertation is of satisfactory language correctness.



Prof C MUNYATI

CHAPTER 1: BACKGROUND TO THE STUDY

1.1 Introduction

There is a general trend of growth in the total quantity of waste that is generated by medical activities in developing countries (Titto *et al.* 2012). This growth is due to a significant increase in the delivery of medical services, as well as an increase in packaging and in the utilization of single use items in the medical field. Another factor is that for public health reasons all waste that has come into contact with infectious materials is treated as infectious waste. Since most medical facilities in developing countries do not adequately segregate infectious or hazardous waste from the ordinary domestic type of waste, the total quantity of waste classified as infectious and thus needing special treatment is greater than would be expected from the increase in medical waste alone (Manga *et al.* 2011).

In this respect South Africa has been one of the focal points in the world because of the dramatic process of change to a transparent and true democracy. Whilst the country is progressing through this continuum of change, the healthcare system is also transforming itself into a district-based system with particular emphasis on a primary healthcare system (Titto *et al.* 2012). Some 40% of all South Africans live in poverty and 75% of these live in rural areas where they were previously deprived of access to the health services. Limited financial resources are available to fund the major changes in all facets of the South African society, and from a sustainable health perspective the priorities are based on providing affordable, accessible, safe healthcare to all of the population (Rogers and Brent 2006).

It is further noted that although South Africa is one of the strongest economies on the African continent, these processes of change and the pressure of expectations pose challenges to the sustainability of the service offerings in the national medical system. Medical waste management is a fundamental strategic function in safe and responsible healthcare and is actively addressed by various bodies such as WHO, UNICEF, USAID, national governments and specifically through various organisations and collaborations such as WHO Technet consultative forum, WHO Safe Injection Global Network (SIGN), and the Global Alliance for Vaccine and Injections (GAVI). In 1998 the WHO Technet forum decided to actively investigate and seek answers to support the objectives of promoting improved medical waste management (WHO 1998) as part of safe injection practices. In South Africa, the poor level of medical waste management had already been identified by the national

government (DOH 1996). A process of transformation of waste management had been initiated separately through a National Waste Management Strategy (DEAT 1999), and the Ministry of Health issued a request for a more affordable solution for the handling of medical waste at rural primary healthcare clinics (DOH 1996). In that respect medical waste incineration has been identified as a potential cost-effective method for medical waste treatment (Rogers and Brent 2006).

Regulations governing the emissions from large commercial Medical Waste Incinerators (MWIs) are stipulated in South Africa (DEAT 2004), which have since been under revision. A less stringent set of performance criteria has been under consideration by the DEAT for the operation of MWIs at primary healthcare clinics, on the basis that although the emission loads are typically higher, the frequency of use of the incinerators is lower and results in a lesser overall emission load into the atmosphere, and the population surrounding the incinerators is less dense, which reduces the consequent exposure of the population to the emissions. In this context the South African Collaborative Centre for Cold Chain Management (SACCCCM) established a protocol for the first quantitative and qualitative evaluation of relatively low cost small-scale incinerators for use at rural primary medical clinics. The practical experience of the programme was shared with members of the WHO Technet and UNICEF Kazakhstan, where similar evaluations had taken place (Rogers and Brent 2006). Firstly, the focus was put on the quantitative analyses of different incinerators in controlled laboratory conditions with identical waste loads. Secondly, qualitative and quantitative analyses of the performance of the incinerators during their use at actual clinics, with guidelines on waste loading procedures, but with no changes to current waste management practices (such as waste streaming and contents of loads). Involvement of all of the stakeholders, including the regulatory authorities, health workers and the communities, was ensured during these analyses. It was also attempted to correlate the field results with the performance analyses in the laboratory. Thirdly, in order to seek acceptance of the regulatory stakeholders to evaluate the performance of the incinerators for each individual clinic site in the trials. This process also indicates to all stakeholders the role that these kinds of incinerators have to play in the management of medical waste in rural primary medical clinics. Finally, the only objective of the trials was to present the DOH with specification guidelines and information upon which a tender specification could be

formulated by the national department for the procurement of small-scale medical waste incinerators for use at rural primary medical clinics (Rogers and Brent 2006).

Medical waste poses serious threats to environmental health because it contains hazardous substances (Manga *et al.* 2011). The hazardous substances include pathological and infectious material, sharps, and chemical waste. In hospitals, different kinds of therapeutic procedures (i.e. cobalt therapy, chemotherapy, dialysis, surgery, delivery, resection of gangrenous organs, autopsy, biopsy, para-clinical test, injections) are carried out and result in the production of infectious wastes, sharp objects, radioactive waste and chemical materials (Hossain *et al.* 2013). Medical waste may carry germs of diseases such as hepatitis B and AIDS (Botelho 2012, Singh and Jain 2011). In developing countries, medical waste has not received much attention and it is disposed of together with domestic waste (Titto *et al.* 2012). Improper medical waste management is alarming in South Africa and it poses a serious threat to public health (Abor 2007). Medical waste contains highly toxic metals, toxic chemicals, pathogenic viruses and bacteria, which can lead to pathological dysfunction of the human body. Medical waste presents a high risk to doctors, nurses, technicians, sweepers, hospital visitors and patients due to arbitrary management (Pasupathi *et al.* 2011). Many problematic waste management issues have been identified for healthcare clinics in South African rural areas (Nemathaga *et al.* 2008) and under-serviced areas in other parts of the world (Agamuthu 2013, Dursun *et al.* 2011a, Haylamicheal and Desalegne 2012, Hossain *et al.* 2011).

1.2 Problem Statement

Medical facilities in the north eastern Free State are in a rural setting, remotely located far away from major routes and centres. North eastern Free State has a population mainly of African origin who were displaced by the former apartheid regime. The regional health facilities that are in the area date back to the late 1980's whilst the district hospital is even older and as such could have not been built with a view to service the current demographic numbers. In Phuthaditjhaba (Qwaqwa), there are the two hospitals (namely, the Mofumahadi Mmanapo Mopeli Regional Hospital and the Elizabeth Ross District Hospital), Bethlehem has four (namely, the Medi-Clinic (Hoogland), Dihlabeng Regional, Phekolong and the Corona Sub Acute Hospitals), Harrismith has one (Thebe Hospital), Ladybrand has one (Mantsopa Hospital), Reitz has one (Nketoana Hospital) and Vrede also has one

(Phumelela Hospital). Several studies (Agamuthu 2013, Basu *et al.* 2012, Forouhar and Hristovski 2012, Fadipe *et al.* 2012, Murthy *et al.* 2011) have noted that the location and remoteness of medical facilities is a cause of concern for the various procedures that could be carried in them; particularly with regard to medical waste management practices. This study, therefore, investigates the medical waste management practices at these vital health facilities in the north eastern Free State area.

1.3 Research Purpose

The main purpose of the study is to investigate the status of medical waste management practices in the health facilities in the north eastern Free State.

1.4 Research Objectives

The objectives of the research are to:

- Describe the current state of operational procedures with regard to the handling of medical waste.
- Analyze the elements of the medical waste chain thereof.
- Compare the differences between current operations against standards for handling medical waste as specified in national medical guidelines for South Africa.
- Identify critical technical and managerial limitations in the delivery of an efficient medical waste handling program.

1.5 Research Hypothesis

The nature and quantity of medical waste generated as well as the institutional practices with regards to sustainable methods of medical waste management including waste segregation and waste recycling are poorly examined and documented in our medical institutions despite the health risks posed by improper handling of medical waste.

Hypothesis: The monthly volume of medical waste generated (y) depends on the size of the facility in terms of hospital beds (x). The null hypothesis posits the absence of such a relationship (i.e. that it does not exist).

1.6 Significance of the Study

The significance of this study is to create public awareness regarding the health risk of the medical waste, to provide relevant recommendations to hospitals and medical centres on possible ways of managing medical waste disposal and also to contribute to the already existing body of academic knowledge. The study, therefore, serves as a source of information for subsequent research in this area. The findings 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. Finally, the study provides directions regarding new and current technologies in medical waste management, not just to the north eastern Free State but to the whole country.

1.7 Definition of concepts

Anatomic waste: consists of recognizable body parts.

Chemical waste: Consisting of, or containing chemical substances, including: laboratory chemicals; film developer; disinfectants expired or no longer needed; solvents, cleaning agents and others.

Genotoxic waste: Consisting of, or containing substances with genotoxic properties, including cytotoxic and antineoplastic drugs; genotoxic chemicals.

Hazardous waste: any material or substance, not included under medical waste that, if handled improperly, has the potential to harm people, property or the environment. For the purposes of these National Environmental Management Act guidelines (DEAT 2007), it includes waste that has the potential to generate noxious or offensive gases as defined in when it is incinerated.

Health research: As defined in the National Health Act (Act No. 61 of 2003), includes any research that contributes to the knowledge of health research.

Health researcher refers to all scientific investigators engaged in health research (Human pathology and improved methods for the provision of health services).

Heavy metals waste: Consisting of both materials and equipment with heavy metals and derivatives, including: batteries, thermometers, manometers.

Incinerator: a fuel burning appliance that is used to dispose of any material by means of combustion. This includes any technical equipment used for the incineration by oxidation of hazardous wastes including pre-treatment as well as pyrolyses or other thermal treatment

processes. It also includes plants burning such wastes as a regular or additional fuel for any industrial process.

Medical waste: any waste which is generated during the diagnoses, treatment or immunization of humans or animals; in research pertaining to this; in the manufacturing or testing of biological agents including blood; blood products and blood contaminated products; any body fluids or excretions; cultures; pathological wastes; sharps; human and animal wastes; isolation wastes; clinical wastes; pathogens; cytotoxic materials; toxic metals and low-grade radio-active materials. Any waste which unless rendered safe may prove hazardous or cause infection when anybody comes into contact with it.

Pharmaceutical waste: Consisting of/or containing pharmaceuticals, including: expired, no longer needed containers and/or packaging, items contaminated by or containing pharmaceuticals (bottles, boxes).

Pressurized containers waste: Consisting of full or empty containers with pressurized liquids, gas, or powdered materials, including gas containers and aerosol cans.

Radioactive materials waste: Includes: unused liquids from radiotherapy or laboratory research; contaminated glassware, packages or absorbent paper; urine and excreta from patients treated or tested with unsealed radionuclides; sealed sources.

Research ethics committee: A multidisciplinary committee charged with the primary objective of protecting research participants through the ethical review, approval and monitoring of research.

Waste incineration processes: Processes for the destruction by incineration of waste that contains chemically bonded halogens, nitrogen, phosphorus, sulphur or metal, or any waste which can give rise to noxious or offensive gases.

(Dursun *et al.* 2011b)

1.8 Structure of the dissertation

The dissertation is organized in six chapters. The abstract contains the main elements, findings and arguments.

Chapter 1 Background

Chapter 1 provides an overview of the study. It contains information on medical waste and types, the challenges and expectations in the management of medical waste

handling. Chapter 1 further identifies tasks, roles and progress of medical waste handling as a science studying medical waste handling from global to local perspectives. In this chapter, a brief background of the study is given, highlighting the need and relevance of the research. The significance of the study, aim, specific research objectives, research hypotheses to be tested and the structure of the dissertation are also given in the chapter.

Chapter 2 Literature review

Chapter two provides a theoretical background to the problem investigated. The literature reviewed in this chapter covers aspects of medical waste management at global and local levels, major factors affecting medical waste handling, current available technologies, treatment and disposal methods, effects of medical waste on the public health, risks associated with medical waste on the environment, animals, general public and the medical personnel, and medical waste management practices, as well as its assessment.

Chapter 3 Materials and Methods

Chapter three presents a description of the study area and the methodology of the study. The materials, methods, and techniques of data collection are described. The chapter also gives an overview of the stages of the study. Details of the conceptual background of medical waste management practices and derivative equations are explained. Finally details of how the data was collected, captured and processed are presented.

Chapter 4 Results and Analysis

In Chapter four, the results of the study are presented in the form of descriptive and graphic statistical presentations. The results include predicted medical waste rates and the sensitivity of this concept under investigation to practices and other related parameters.

Chapter 5: Discussions

Chapter five deals with the discussion of the results and the limitations of the study are presented.

Chapter 6 Conclusions and recommendations

In Chapter six, the conclusions drawn and recommendations of the study are given.

1.9 Summary

This chapter outlined the aim of the study, problem statement, purpose, objectives, hypotheses, significance and structure of the research. The next chapter deals reviews available literature relating to medical waste management practices.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The growing number of medical facilities in many parts of the world in the past decade has resulted in an increase in generation of medical waste (Agamuthu 2013, Manga *et al.* 2011). These medical facilities include hospitals, clinics, medical laboratories, pharmacies and any support medical services. The total waste stream generated from these facilities is known as medical waste (Haylamicheal and Desalegne 2012). This waste contains hazardous and non-hazardous waste. The non-hazardous waste consists of general domestic waste. The hazardous waste may include a variety of types, such as infectious, pathogenic, genotoxic, chemical, pharmaceutical, sharps, and waste with heavy metals content, pressurized containers, and radioactive material (Voudrias *et al.* 2012). According to the World Health Organization (WHO), the hazardous waste fraction represents 10 - 25% of the total healthcare waste (WHO 2011a). According to several studies (Bella *et al.* 2012, Komilis *et al.* 2012, Yan *et al.* 2012, Brown *et al.* 2011, Haylamicheal and Desalegne 2011, Mandal *et al.* 2011, Manga *et al.* 2011, Pfister *et al.* 2011) this category of waste is one of the most problematic types for municipal solid waste authorities in developing countries. When such waste enters the municipal solid waste stream, pathogens and hazardous substances pose a great risk to the environment and to those who come in contact with the waste (Titto *et al.* 2012).

2.2 Medical Waste

Medical waste may be defined as any undesirable or superfluous by-product, emission, residue or remainder generated by in the course of health care by medical professionals and medical facilities, which is discarded, accumulated and stored with the purpose of eventually discarding it, or is stored with the purpose of recycling, re-using or extracting a usable product from such matter (WHO 2011a). Medical waste may, if handled improperly, have the potential to harm people, property or the environment. In this regard, all human anatomical waste, blood and body fluids are considered to be potentially hazardous. The unsafe disposal of such waste could have detrimental effects for people who might come into contact with medical waste (Agamuthu 2013).

Medical waste is classified as either: (i) Not hazardous and is called Medical General Waste (MGW) or (ii) Hazardous and is called Medical Risk Waste (MRW). Hazardous waste management is a concern for every medical organization (Akbolat *et al.* 2011). Types of hazardous medical waste include infectious waste; pathological waste, including body fluids, secretions and surgical specimens, sharps, especially contaminated sharps; pharmaceutical waste; chemical waste; heavy metals; radioactive waste; genotoxic waste; cytotoxic agents, and pressurized containers. Most waste generated in medical establishments can be treated as regular solid municipal waste (Akinci *et al.* 2012, Al Sabbagh *et al.* 2012, Farzadkia *et al.* 2012, Forouhar and Hristovski 2012, Seng *et al.* 2011, Wang and Geng 2012). But a varying proportion of medical waste requires special attention, including sharps (e.g. needles, razors, and scalpels), pathological waste, other potentially infectious waste, pharmaceutical waste, biological waste, and hazardous chemical waste (Tables 1 - 2). Collectively, these types of waste are known as special MRW (Komilis *et al.* 2012, Haylamicheal and Desalegne 2012, Voudrias *et al.* 2012). In addition, all waste generated under certain circumstances, such as in isolation wards and microbiological laboratories, requires special attention. Other waste streams generated by MGW could include packaging, reusable medical equipment, and secondary waste created through disposal technologies (Komilis *et al.* 2012, Titto *et al.* 2012, Yan *et al.* 2012, Brown *et al.* 2011, Ho and Liao 2011, Montoneri *et al.* 2011). In South Africa the classification of medical waste follows.

Table 1 Classification of the Different Types of Medical Solid Waste

Types of waste	Composition
General	Packaging materials (mostly cardboard), office paper, leftover food, cans, plastics bags and containers.
Medical Infectious waste	Clinical specimens, culture plates, drainage bags, surgical waste, autopsy waste, blood, blood products and body fluids
Medical Pathological waste	Human tissues, organs, foetuses, placentas, amputated body parts and other body parts
Medical Solid chemicals and pharmaceutical waste	Spilled or expired drugs and chemicals
Sharps	Needles, syringes, blades, broken glass, scalpels.

Source: WHO 2011a

Table 2 Medical Waste Categories and Description

Waste category	Description and examples
Infectious waste	Waste suspected of containing pathogens e.g. laboratory cultures, waste from isolation wards, tissues, materials or equipment having been in contact with infected patients, excreta.
Pathological waste	Human tissue or fluids e.g. body parts, blood and other body fluids, human foetuses.
Sharps	Sharp waste e.g. needles, infusion sets, scalpels, knives, blades, broken glass.
Pharmaceutical waste	Waste containing pharmaceuticals e.g. pharmaceuticals which are expired or no longer needed, items contaminated or containing pharmaceuticals (bottles, boxes).
Genotoxic waste	Waste containing substances with genotoxic properties e.g. waste containing cytotoxic drugs (often used in cancer therapy), genotoxic chemicals.
Chemical waste	Waste containing discarded chemical substances e.g. laboratory reagents, film developer, disinfectants which are expired or no longer needed, solvents.
Wastes with high content of heavy metals	e.g. batteries, broken thermometers, blood pressure gauges.
Pressurized Containers	e.g. gas cylinders, cartridges and aerosol cans
Radioactive waste	Waste containing radioactive substances e.g. unused liquids from radiotherapy or laboratory research, contaminated glassware, packages or absorbent paper, urine and excreta from patients treated or tested with unsealed radionuclides.

Source: WHO 2011a

2.3 E-waste and PCB's

Recently there has been an additional class of medical waste arising from the surge in use of small medical units (Achillas *et al.* 2013, Liu *et al.* 2012, Pant *et al.* 2012, Khetriwal *et al.* 2011, Manhart 2011, Ongondo *et al.* 2011, Chancerel *et al.* 2011). Electronic waste or E-waste comprises of old, end-of-life electronic appliances such as computers, laptops, TVs, DVD players, mobile phones, MP3 players, which have been disposed of by their original users. E-waste contains many hazardous constituents that may negatively impact the environment and affect human health if not properly managed (Habib *et al.* 2013, Taghipour *et al.* 2011). Various organizations, bodies, and governments of many countries have adopted and/or developed environmentally sound options and strategies for E-waste management to tackle the ever growing threat of E-waste to the environment and human health (Liu *et al.* 2012, Ullah and Khan 2011, Wath *et al.* 2011) as it is often disposed of with medical waste termed the Waste Electrical and Electronic Equipment (WEEE) (Goorhuis *et al.* 2012, Stasiskiene *et al.* 2011, Rotter *et al.* 2011, Tsydenova and Bengtsson 2011).

According to Kuo (2011), one obsolete PC with a cathode ray tube monitor consists of metal (43.7%), plastics (23.3%), other electronic components (17.3%) and glass (15%). Within the metals, there are highly toxic metals such as lead, mercury and cadmium (Idoko *et al.* 2012, Pant *et al.* 2012, Karliner and Orris 2011); and, precious metals such as silver, gold, copper, and platinum (Kuo 2011). Within the plastics, we find polybrominated diphenyl ethers (PBDEs) used as flame retardants. This is an addition onto another group (Figure 1) of persistent organic pollutants (POPs), the polychlorinated biphenyls (PCBs) (Du *et al.* 2013, Liu *et al.* 2013, Lau *et al.* 2012, Yan *et al.* 2012, WHO 2011b). The use of PCBs and POPs creates serious contamination problems and calls for specialised bioremediation efforts (Pierce *et al.* 2013).

Compound	Structure	Compound	Structure
PCB		PFOS	
PCDD		Fluorinated telomer alcohols	
PCDF		PBDE	
HCB		HCH	
PCBz		HCBD	

Figure 1 Structure of Selected Chlorinated, Brominated and Fluorinated POPs or PCBs Precursors

(Source: Weber *et al.* 2011:109).

Inappropriate dismantling, storage and transporting of e-waste may result in human and environment exposure to those hazardous materials (Liu *et al.* 2013, Xue and Xu 2013). Kuo (2011) mentions that with importing and exporting activities of e-waste between nations, this increasingly large stream of hazardous waste in transport poses a threat at a global scale (Figure 2).

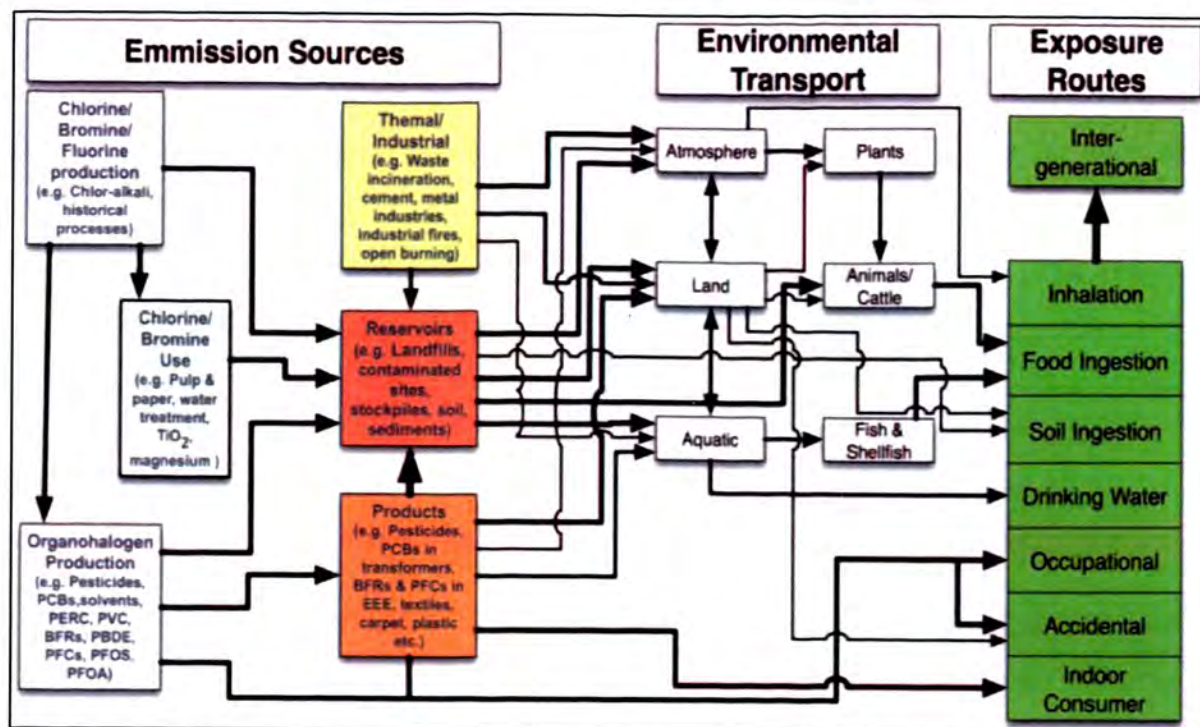


Figure 2 Substance Flow of POPs/Persistent Toxic Substances and Human Exposure

(Source: Weber *et al.* 2011: 110).

For example, it is assumed that a global e-waste production of 20 million tons per year, which would result in an annual global emission from e-waste recycling, would contain a total of 198,000 tons of chromium, 820,000 tons of copper, 206,000 tons of nickel, 102,000 tons of zinc and about 50,000 tons of lead and tin respectively. This possibility for pollution is obviously a critical ecological and human health problem. On the upside, recyclers retrieve copper and other precious metals permitting their reuse thereby decreasing the amounts of new ores that must be mined. Clearly, safe recycling and reuse of e-waste would benefit both internationally as well as locally (Kuo 2011).

2.4 Medical Waste Management

According to Komilis *et al.* (2012), Nabizadeh *et al.* (2012), Titto *et al.* (2012), Haylamicheal *et al.* (2011) and Manga *et al.* 2011, the activities associated with the management of medical solid waste (MSW) in South Africa can be grouped into five functional elements: (1) generation, (2) separation, packaging and labelling, (3) on-site collection, transport, and provisional storage, (4) off-site transportation and (5) treatment and disposal. Medical waste is relatively not as abundant as municipal waste yet despite the

relatively lower quantity of hazardous waste generated the risk to cause adverse effects are significant if it is not managed appropriately. Therefore, hazardous medical waste should be identified, quantified, segregated, handled, treated and disposed of properly. Incineration is still a widely used treatment method for most hazardous medical waste (Agamuthu 2013, Ciplak and Barton 2012, Hossain *et al.* 2011, Voudrias *et al.* 2012, Bella *et al.* 2011, Fadipe *et al.* 2011, Geng *et al.* 2011, Ho and Liao 2011, Khammaneechan *et al.* 2011, WHO 2011b).

In the last few years, many researchers in both developed and developing countries have investigated the practices of medical waste management at selected medical facilities within their countries (Sushma *et al.* 2012). Medical waste in both developed and developing countries presents hazards of disease or injury among workers and has been a cause for concern (Basu *et al.* 2012, Mohankumar 2012, Patwary and Sarker 2012). Studies on medical waste have been reported in several countries such as Afghanistan (Forouhar and Hristovski 2012) and Algeria (Sefouhi *et al.* 2011). Other studies include those done in Bahrain (Al Sabbagh *et al.* 2012), Bangladesh (Chowdhury *et al.* 2011, Dana 2011, Patwary *et al.* 2012, 2011a, b, Syed *et al.* 2012), Cameroon (Manga *et al.* 2011, Mochungong *et al.* 2011a, b), China (Du *et al.* 2013, Geng *et al.* 2013, Wang and Geng 2012) and Ethiopia (Anagaw *et al.* 2012, Bella 2012, Haylamicheal and Desalegne 2012). Similar studies were also carried out in Ghana (Abor 2013, Sasu *et al.* 2012), Greece (Achillas *et al.* 2011, Voudrias *et al.* 2012, Komilis *et al.* 2011). Most research seems to have been done in India (Bhaskar *et al.* 2012, Gupta *et al.* 2012, Mohankumar and Kottaiveeran 2012, Patel *et al.* 2011).

Other studies have been carried out in Indonesia (Sari *et al.* 2011), Iran (Askarian *et al.* 2012, Bazrafshan and Mostafapoor 2011, Hassanvand *et al.* 2011, Farzadkia *et al.* 2012, Ferdowsi *et al.* 2012, Jabbari *et al.* 2012, Lakbala *et al.* 2012, Nabizadeh *et al.* 2012), Israel (Elimelech *et al.* 2011), Japan (Hamasuna *et al.* 2011), Lao People's Democratic Republic (Shanmugasundaram *et al.* 2012), Malaysia (Hossain *et al.* 2012, Mohamed *et al.* 2011), Mongolia (Kakizaki *et al.* 2011) and Nigeria (Afon 2012, Chima *et al.* 2011, Idoko *et al.* 2012, Ogbonna *et al.* 2012, Ogbonna 2011, Jiburum and Jiburum 2012, Johnson 2012, Morenikeji 2011, Wahab and Adesanya 2011). Investigation of medical waste management practices has been done in Pakistan (Aklobat *et al.* 2011). Other places where medical waste has been studied include Palestine by Al-Khatib *et al.* (2011), in Qatar by Al-Maaded 2012, in Serbia by Gavrancic *et al.* (2012) and Ratkovic *et al.* (2012).

Medical waste management research was done in South Africa by, by among others, Mangizvo and Wiseman (2012), Titto *et al.* (2012), Musee (2011) and Nemathaga *et al.* (2008). In other countries research has been done in Spain by Díaz *et al.* (2012), Taiwan (Ho and Liao 2011), Tanzania (Kagonji and Manyele 2011), Thailand (Khammaneechan *et al.* 2011), Turkey (Akinci *et al.* 2012, Ciplak and Barton 2012, Dursun *et al.* 2011a, b, c), Uganda (Katusiimeh *et al.* 2013, Mugambe *et al.* 2011), UK (Mandal *et al.* 2011, Mannion 2011), USA (Agar 2012, Agar *et al.* 2012, Berwick and Hackbarth 2012, Brook 2011, Kim *et al.* 2011, Gerba *et al.* 2011, Grimmond and Reiner 2012, Miller *et al.* 2012, Perry *et al.* 2012, Rebmann *et al.* 2011a, b), Vietnam (Kühling and Pieper 2012, Chi and Long 2011) and Yemen (Al-Emad 2011).

Most studies reveal repeated themes of (a) deficiencies in training, health and safety measures for the staff, (b) limited budget for the waste management, (c) gaps within the management structure as well as (d) poor legislation, planning and guidance at the country level. Most researchers concluded that management practices of such waste, especially the hazardous portion, represent a challenge in their countries due to deficiency in waste generation data and/or gaps in the management framework. In addition, absence of medical waste management plan at the country level and unavailability of suitable treatment and disposal options can further hinder the waste management efforts (Mathur *et al.* 2011, 2012).

The importance of proper medical waste management practices has become significant within the past decade after many developing countries, including South Africa, started to formulate their general environmental legislation. This legislation applies to a wide range of establishments including manufacturing, infrastructure, and services such as healthcare. In 2007 South Africa issued an environmental management bill (DEAT 2007) for managing both healthcare and solid municipal waste. The bill outlines key requirements for waste generators, transporters, treatment facilities, and export and import issues. The purpose of the NEMA is to reinforce the National Environmental Management: Air Quality Act, 2004 (NEM: AQA), to provide for environmental management inspectors to be peace officers, to provide for the imposition of a penalty for the offence of failing to comply. However, there are few published studies assessing the status of healthcare waste management, in particular the hazardous portion, at the national level.

2.5 State of Technologies

The safe and effective handling of medical waste depends on appropriate segregation, packaging, in-house transport, and storage procedures (Agamuthu 2013, Aksakal *et al.* 2011, Manga *et al.* 2011, Omar *et al.* 2012, Titto *et al.* 2012, WHO 2011a). Cytotoxics are highly hazardous (Ciplak and Barton 2012, Voudrias *et al.* 2012, Hossain *et al.* 2011). When using incineration, which is popular in the study area though the technology is old, full destruction of cytotoxic substances can only be achieved at temperatures exceeding 1100°C. Two stage incinerators, pyrolytic incinerators, retorts and plasma furnaces with second stage or after-burn temperatures of >1100°C, and two-second-residence time are recommended for treatment. Radioactive waste should be managed at source, separated from MRW and not sent to the MRW treatment facilities. Small quantities of low-level radioactive infections waste could be sent to pyrolytic incinerators and plasma furnaces (Pasupathi *et al.* 2011).

According to Mathur *et al.* (2012) and Mohankumar and Kottaiveeran (2012), the MRW treatment technologies more commonly used are incineration (i.e. autoclave and hydroclave), chemical treatment including pyrolysis, (e.g. with chlorine, glutaraldehyde), Sterilization (e.g. with ethylene oxide, formaldehyde, oil heated screw feed technology, Cobalt-60 gamma rays, ultra-violet, electron beam), microwave treatment, plasma arc and steam based thermal treatment (e.g. autoclaving). Incineration of MRW is widely used worldwide (Agamuthu 2013, Longe 2012, Astrup *et al.* 2011, Dursun *et al.* 2011b, Hossain *et al.* 2011, Ma *et al.* 2011, Manga *et al.* 2011, WHO 2011b, Zhang *et al.* 2011a). Incineration has been the preferred means of treating and disposing of medical waste in South Africa (Titto *et al.* 2012). Incineration is the burning of waste in temperatures ranging from 800 to 1200°C (Astrup *et al.* 2011). It utilizes combustion to decline waste materials to non-combustible residue or ash and exhaust gases, and has been claimed as the most effective means for destroying infectious and toxic components, and for significantly reducing volume and weight (Murthy *et al.* 2011). Earlier incinerators used a single combustion chamber where MRW was burned at temperatures of between 800 and 1100°C under high excess air conditions. This type of incinerator does not comply with current legislation in South Africa. More modern incinerators use two-stage combustion of MRW and are supplied with gas clean-up systems. In the first chamber, MRW is pyrolysed under reducing conditions and temperatures between 800 and 900°C. Gases from the first chamber pass into a second

chamber where incombustibles are burnt at temperatures of 1100 to 1200°C, resulting in the formation of mainly carbon dioxide and water (Ma *et al.* 2011). Ash produced from the incineration of HCRW is regarded as hazardous and can be disposed of at a permitted site – unless the ash is declassified (Wath *et al.* 2011).

Autoclave treatment is a process of steam sterilization under pressure. It is a low heat process in which steam is brought into direct contact with the waste material for duration sufficient to disinfect the material. These are also of three types: Gravity-type, Pre-vacuum type and Retort type (Pasupathi *et al.* 2011). In the first type (Gravity type), air is evacuated with the help of gravity alone. The system operates with temperature of 121°C and steam pressure of 15 psi for 60 - 90 minutes. Vacuum pumps are used to evacuate air from the Pre-vacuum autoclave system so that the time cycle is reduced to 30 - 60 minutes. It operates at about 132°C. Retort type autoclaves are designed to handle much larger volumes and operate at much higher steam temperature and pressure. Autoclave treatment has been recommended for microbiology and biotechnology waste, waste sharps, soiled and solid wastes.

The main disadvantage of medical waste incineration, however, is the emission of pollutants, some of them extremely toxic to the atmosphere. Pollutants are usually emitted either in condensed or in gaseous phases (Tan and Xiao 2012). Many organic and metallic compounds have known effects on human health and the environment. Among the latter compounds, polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran (PCDD/F) in exhaust gases are of major concern. Generation and release of PCDD/Fs have created great public concerns due to their acute and chronic health effects, such as immune, endocrine, reproductive and carcinogenic malfunctioning potential (Haylamicheal and Desalegne 2012, Weber *et al.* 2011, WHO 2011b).

2.6 Chemical Treatment

Destruction of pathogens or the disinfection of MRW can be achieved by chemical treatment and is cheap. This treatment is recommended for waste sharps, solid and liquid wastes as well as chemical waste (Dursun *et al.* 2011b, Hossain *et al.* 2011). Chemical treatment involves use of at least 1% hypochlorite solution with a minimum contact period of 30 minutes or other equivalent chemical reagents such as using chlorine gas, ethylene oxide, formaldehyde, formaldehyde-alcohol combination, hexachlorophene, iodine, iodine-alcohol combination, propylene, phenolic compounds. Waste is commonly shredded to increase exposure to the reactant, placed into a vessel and sealed.

The effective action of the chemical reagent is enhanced by eliminating any vacuums in the medical waste, before pumping the chemical into the vessel. Gaseous chemicals are neutralized, filtered or scrubbed before being emitted into the atmosphere. Storage and handling of chemicals by operating staff requires training and care. Chemical disinfection of MRW often does not eliminate most micro-organisms. However; it may be an appropriate treatment option for rural clinics with small MRW generators. Anatomical waste and hazardous chemical waste should not be treated chemically (Haylamicheal and Desalegne 2012). In the USA, chemical treatment facility is also available in mobile vans. In one version, the waste is shredded, passed through 10% hypochlorite solution (dixichlor) followed by a finer shredding and drying (Pasupathi *et al.* 2011). Pyrolysis - or heating without oxidation - avoids the toxic emissions produced by incineration by using intense electric heat to break organic molecules down into clean-burning gas. The glowing gas created in an arc by the passage of current is called plasma. By blowing a steady stream of gas through an arc, a plasma torch is created, with temperatures many times hotter than those produced by ordinary combustion. The plasma pyrolysis process uses a plasma torch to gasify the organic material in medical waste while converting the metallic and siliceous fractions into an inert glassy slag. The product gas can be used on-site as a fuel; the slag is suitable for use as aggregate in road building or in other applications (Mathur *et al.* 2012).

2.7 Sterilization

Sterilization can generally be defined as any process that effectively kills or eliminates all microorganisms like fungi, bacteria, viruses and spore forms except prions from a surface, equipment, food, medication or biological culture medium. Although sterilization can be

used in many different fields of industry, medical and surgical fields are some of the most important fields that the sterilization is required for but it is strictly required for surgical gloves and instruments that are used in direct contact with the blood stream or normally sterile body tissues. It can also be used for the sterilization of implantable devices and medical devices (Mathur *et al.* 2012).

Each sterilization method has advantages as well as disadvantages. Dry heat sterilization has advantages in that it is non-toxic and safe for the environment (Aghapour *et al.* 2013). Most powders, soft paraffin, and glycerine can be sterilized by this method. It is disadvantageous in that it needs high heats for long periods; the penetration of the heat takes a long time in large devices and is not suitable for plastic and cloths (Silindir and Özer 2009). Pressured vapour sterilization is economic, requires short processing time, is non-toxic and safe for the environment but cannot sterilize materials that are sensitive to high heats and moisture, oily materials like soft paraffin, liquid materials and electrical devices (Aghapour *et al.* 2013). Ethylene oxide (EtO) sterilization is preferable for materials that are sensitive to heat. There is no limit for lumen. It also ensures complete penetration depending on the use of the permeable gas. It is important to define the sterility assurance level (SAL) with the use of biological indicators. Disadvantages of ethylene oxide include the fact that time of the sterilization and ventilation is long. EtO is toxic, carcinogenic, flammable, and explosive. It needs an aeration period after the process because of the formation of ethylene chlorohydrin (Silindir and Özer 2009).

Formaldehyde sterilization is preferable for materials that are sensitive to high heat and there is no need for ventilation of materials after sterilization. However, it is toxic and carcinogenic so it cannot be used for the sterilization of liquids. Gas plasma - Hydrogen peroxide (H_2O_2) sterilization is safe for the environment and it is also less hazardous to work with. Sterilization can be achieved in a period between 28 minutes to 74 minutes. There is no need for the ventilation. It is proper for the sterilization of materials that are sensitive to temperature (Aghapour *et al.* 2013). It is not a proper method for the sterilization of liquids. Measuring the hydrogen peroxide concentration within the isolator during sterilization cycles in real time may also be a problem. Peracetic acid sterilization is a single-use process; there is no possibility of contamination but only one or a small number of instruments can be processed in a cycle and the use of the materials after sterilization process is not possible. Both Gamma radiation and E-beam sterilization are advanced technological

methods. They are cold methods; increase in temperature is so slight and have a high SAL. Both the Gamma radiation and E-beam sterilization methods are very easy in that control can be achieved only by the parameter of applied dose. The former has no dose flexibility because the dose rate is lower than electron beams and the latter needs an electron accelerator that is very rare (Silindir and Özer 2009).

Irradiation sterilization uses Cobalt-60 gamma rays, ultra-violet or electron beams. Gamma rays are formed with the self-disintegration of Cobalt - 60 (^{60}Co) or Caesium - 137 (^{137}Cs). Irradiation sterilization is a high penetrating and commonly used sterilization method. It is generally used for the sterilization of gaseous, liquid, solid materials, homogeneous and heterogeneous systems and disposable medical equipment, such as syringes, needles, cannulas, density materials, cosmetics and intravenous sets. It can easily be applied on many materials but is incompatible with polyvinyl chloride (PVC), acetal and polytetrafluoroethylene (PTFE). It is a continuous or batch process. Complete penetration can be achieved depending on the thickness of the material. It supplies energy saving and it needs no chemical or heat dependence (Silindir and Özer 2009). According to Mathur *et al.* 2012, depending on the radiation protection rules, the main radioactive source has to be shielded for the safety of the operators. Storage of is needed depending on emitting gamma rays continuously. Immediate (dosimetric) release can be done because it needs no sterilization testing after the completion of the process. Another advantage is it has no residue after the sterilization process (Mathur *et al.* 2012). Ultra-violet irradiation operates as a germicidal lamp and is only used for the sterilization of surfaces and some transparent objects. But, it is not used for the sterilization of contaminated areas and plastics and is not an official technique for drugs and medical devices. Depending on the type of the subatomic particles, subatomic particles may be generated by a device or a radioisotope. Thus, their ability of penetration may change. It is not an official sterilization method for drugs and medical devices nowadays (Silindir and Özer 2009).

Electro-beam sterilisation (E-beam sterilization) is commonly used for the sterilization of medical devices like gamma radiation sterilization. E-beam sterilization can be generally made by the use of e-beams that are obtained from the accelerator and by isotope method. Its advantage is the need of very short exposition time depending on the 10 MeV of very high electron energy. This high energy is fundamental for an effective

sterilization. While 15 minutes is sufficient for the accelerator method, the isotope method requires 24 hours. ^{60}Co isotope source is generally used for the isotope method. The energy of the produced and accelerated electrons is increased by specially designed machines. An on-off technology that operates with electrical energy is used. It is a continuous process, and can be applied to many materials depending on its penetration. Immediate release can be done because it needs no sterilization testing after the completion of the process. The most important advantage about e-beam radiation is it's having much higher dosing rate than gamma or X-rays. Another advantage is having no residue after sterilization process. The use of higher dose rate causes less exposure time and reduced potential degradation to polymers. A limitation about the use of e-beams is their less penetration through any material than gamma or X-rays (Silindir and Özer 2009).

It is possible to collect all the properties of E-beam sterilization in a series. E-beam sterilization is a United States Food and Drug Administration (USFDA) approved process. It is recognized and accepted by international standards organizations. It has several advantages such that it can penetrate a variety of product packaging materials including foils, can cause no damage to sterile seals on packaging and also allows the control of temperature during irradiation process. Again a well-controlled dose range can be achieved since the process is cost effective though the construction of the e-beam sterilization institution is expensive. It is a fast process in very small lots which affects the efficacy of the procedure and for immediate access to fully sterilized and shippable product. It gives dose very rapidly for protecting the properties of the product and has minimal effect on atmosphere. The only effect is the formation of slight amount of ozone. Personnel have to wear protective clothes for the harmful effects of e-beam. For the sterilization procedure, validation guidance documents can be used for the implementation and start up. Lastly characteristics of the e-beam mainly depend on the absorbed dose and the accelerated energy (Silindir and Özer 2009).

2.8 Microwave Technology

The use of microwave energy for the destruction of MRW is an alternative technology to incineration (Titto *et al.* 2012, WHO 2011a). The United States Occupational Safety and Health Administration (OSHA) regard microwave energy as a non-ionizing radiation. Microwave generators emit below $10\text{mW}/\text{cm}^2$ of energy at a frequency of 2 450 MHz. It is

important not to compare the exposure from X-ray machines with microwave generators. X-ray machines produce ionizing radiation and can destroy human tissue operating at frequencies of $\leq 10\,000\text{GHz}$ (Hossain *et al.* 2011, Ohtsu *et al.* 2011). Pasupathi *et al.* (2011) mention that microwave technology is a wet thermal disinfection technology but unlike other thermal treatment systems, which heat the waste externally, microwave heats the targeted material from inside out, providing a high level of disinfection. The input material is first put through a shredder. The shredded material is pushed to a treatment chamber where it is moistened with high temperature steam. The material is then carried by a screw conveyor beneath a series of conventional microwave generators, which heat the material to $95 - 100\text{ }^{\circ}\text{C}$ and uniformly disinfect the material during a minimum residence time of 30 minutes and the total cycle is of 50 minutes. A second shredder fragments the material further into unrecognizable particles before it is automatically discharged into a conventional / general waste container. This treated material can be landfilled provided adequate care is taken to complete the microwave treatment (Singh and Jain 2011). In the modern versions, the process control is computerized for smooth and effective control.

Microwave technology has certain benefits, such as absence of harmful air emissions (when adequate provision of containment and filters is made), absence of liquid discharges, non-requirement of chemicals, reduced volume of waste (due to shredding and moisture loss) and operator safety (due to automatic hoisting arrangement for the waste bins into the hopper so that manual contact with the waste bags is not necessary). However, the investment cost is high at present. Microbiology and biotechnology waste, waste sharps, soiled waste and solid waste are permitted to be microwaved (Pasupathi *et al.* 2011, Titto *et al.* 2012).

2.9 Plasma Arc Technology

Plasma arc technology is widely used in the metallurgical smelting industry. North Atlantic Space Agency (NASA) uses it for testing heat shields that protect space vehicles on re-entry (NASA 2012). Plasma arc torches can produce temperatures of between $8\,000$ and $20\,000\text{ }^{\circ}\text{C}$. The high temperatures in the plasma arc break down waste or molecular structures to their elemental components. Organic compounds are converted to fuel gas, primarily hydrogen and carbon monoxide. Electrical energy is used to generate the plasma arc. The plasma gas is applied through a different port into the arc to finely divided material.

Organic materials are vaporized. Inorganic material and metals are melted together into a molten bath, which produces lava-like chunks of rock when cooled. The plasma process is endothermic (heat is absorbed) whereas incineration is an exothermic reaction (heat is released). Oxygen is not directly required but it is usually introduced in a controlled fashion to enable the production of fuel gas. The gas from the plasma process has to go through an environmental gas clean-up (ECG) system to remove particulates, heavy metals, organics and other pollutants (Chang *et al.* 2012, Zhang *et al.* 2012, Popov *et al.* 2011).

2.10 Steam-based treatment

Steam sterilization, or autoclaving, is a process to sterilize medical waste prior to disposal in a landfill (Aghapour *et al.* 2013). Steam sterilization treatment combines moisture, heat and pressure to inactivate microorganisms (Titto *et al.* 2012). All steam autoclaves are constructed with a metal chamber to withstand the increased pressure/temperature. The factors that affect the efficacy of steam autoclave treatment of medical waste are those affecting the internal waste load temperature, steam penetration of the waste, and the duration of treatment (Ferdowsi *et al.* 2012, Dursun *et al.* 2011b). Steam-based thermal treatment uses steam as a sterilizing agent that renders HCRW sterile to the level of a 6 log₁₀-kill (99.9999%). The term 'kill' means microbial inactivation. Log₁₀-kill is defined as the difference between the logarithms of number of viable test microorganisms before and after treatment. A log₁₀-kill of 6 is equivalent to a millionth (0.000001) survival probability in a population, or a 99.9999% reduction of the population. It is common in steam-based technologies to shred the waste before treatment (Ji *et al.* 2012).

Hydroclave is innovative equipment for steam sterilization process (like autoclave) (Titto *et al.* 2012). It is a double walled container, in which the steam is injected into the outer jacket to heat the inner chamber containing the waste. Moisture contained in the waste evaporates as steam and builds up the requisite steam pressure (35 – 36 psi). Sturdy paddles slowly rotated by a strong shaft inside the chamber tumble the waste continuously against the hot wall thus mixing as well as fragmenting the same. In the absence of enough moisture, additional steam is injected. The system operates at 132°C and 36 psi. steam pressure for sterilization time of 20 minutes. The total time for a cycle is about 50 minutes, which includes start-up, heat-up, sterilization, venting and de-pressurization and dehydration. The treated material can further be shredded before disposal. The expected

volume and weight reductions are up to 85% and 70% respectively. The hydroclave can treat the same waste as the autoclave plus the waste sharps. The sharps are also fragmented. This technology has certain benefits, such as absence of harmful air emissions, absence of liquid discharges, non-requirement of chemicals, reduced volume and weight of waste (Doona *et al.* 2012, Ji *et al.* 2012, Sagripanti *et al.* 2011, Pasupathi *et al.* 2011).

In most recent applications, waste is shredded either during or after sterilization, making the waste unrecognizable. The dry, sterilized waste leaving the sterilizer can be disposed of at a normal landfill site after de-classification. A common steam sterilizer is an autoclave where high temperature and pressure are used to destroy micro-organisms. Hospitals use autoclaves to sterilize instruments before and after use (Hossain *et al.* 2012, Titto *et al.* 2012). A major difficulty associated with steam sterilization is ensuring the sufficient residence time to guarantee pathogen destruction and the more limited capacity of most autoclaves compared with incineration (Ji *et al.* 2012, Dursun *et al.* 2011a and b).

2.11 Electro Thermal Deactivation (ETD)

This process uses low frequency radio waves and an imposed high-energy field to inactivate medical waste, and destroy pathogens such as viruses, vegetative bacteria, fungi, yeast and spores, without combusting the waste (Zhang *et al.* 2012). The processed waste, with a microbial level reduced by six logs, can then be recycled. The ETD process converts the MRW into treated decontaminated solid waste. This process involves the pre-shredding of the waste, addition of water, compaction of the waste, and exposure to a low frequency oscillating electric field (RF unit) (Titto *et al.* 2012). The electrical energy is transferred to the waste fragments, and water, which rapidly heat to temperatures of 95 to 100°C. Sterilization of the waste takes place in an insulated, fully enclosed tube offering waste a two-hour residence time. The treated waste is cooled and compacted before disposal to a landfill site. The entire waste shredding and sterilization process operates under vacuum. Gas used in the process is filtered before being discharged into the atmosphere. This process generates no liquid effluent. Operating ETD plants can process up to 50 tonnes per day of MRW (Su *et al.* 2012).

The use of ETD is most effective with materials that contain polar molecules such as water, which is the major component of microorganisms, including all human pathogens (Aguayo-Villarreal *et al.* 2011). Polar molecules have an asymmetric electronic structure and

tend to align themselves with an imposed electric field. When the polarity of the applied field changes rapidly, the molecules try to keep pace with the alternating field direction, thus vibrating, and in the process dissipating energy as heat. The electric field created by ETD causes high molecular agitation and thus rapidly creates high temperatures within the microbial cell. This causes the microbial cell to rupture and die. All of the molecules exposed to the field are agitated simultaneously and, accordingly, heat is produced evenly throughout the waste – instead of being imposed from the surface as in conventional heating (Su *et al.* 2012, Zhang *et al.* 2012).

This phenomenon, called volumetric heating, transfers energy directly to the waste, resulting in uniform heating throughout the material, eliminating the inherent inefficiency of first transferring heat from an external source to the surface of the waste, and then to the interior. ETD uses a radio frequency that maximizes the inactivation of the physical medical waste, enabling the treatment process to kill pathogens while maintaining the temperature of the rest of the waste below 95°C. From the collection point, the container contents are discharged into the processing system by automatic handling equipment, after which the containers are placed on a separate conveyor where they are washed with detergents, disinfected and dried before being returned to service. In the processing system, a heavy-duty, size-reduction mill crushes and shreds the waste into small particles of a relatively uniform size, which are deposited onto a sealed conveyor and transported to the ETD. Here, the ground-up waste material and fines are mixed with a small amount of water, compressed and extruded into the ETD tube. The waste is then processed by the selective absorption of energy, dipolar rotation of liquid molecules, and an imposed high-energy field. Since the ETD technology emits no pathogenic solid material, liquids or air particles, a stream of safe solids are processed with no environmental degradation of any kind. In the compacting room, the treated waste is delivered into a standard compactor box, reducing the volume by as much as 85%. The material can now either be disposed at a general landfill site or, where possible, recycled (Su *et al.* 2012). The summary of these treatment technologies, advantages and disadvantages are given in Table 3.

2.12. Effects of Medical Waste on Public Health

Waste generated from medical activities can result in negative impacts on public health if there is inappropriate treatment and disposal. Medical waste may play an important role

in the transmission and intensification of disease (Aghapour *et al.* 2013). This is a growing concern in developing countries. Hazards associated with waste produced by medical establishments (MEs), and the increased potential for infection and injury, have been frequently described. There is particular concern that an informal sector dealing with the recycling of medical waste components may contribute to transmission of disease, especially among waste collectors, scavengers and recycle-operators (Titto *et al.* 2012, Patwary *et al.* 2011 and Umar and Yaro 2011).

Table 3 Hazardous Medical Waste Treatment Technologies

Parameters influencing Incineration	Advantages of Incineration	Disadvantages of Incineration
• Turbulence and mixing • Moisture content of waste • Filling of combustion chamber • Temperature and residence time • Maintenance and repair	• Reduction of waste volume and weight • Ability to make waste unrecognizable • Acceptability for all waste types • Heat recovery potential	• Public opposition • High investment, operation cost • Formation of dioxins and furans • High maintenance, testing and repair costs • Vulnerability to future restrictive emission laws
Parameters influencing Steam Autoclave Disinfection	Advantages of Steam Autoclave Disinfection	Disadvantages of Steam Autoclave Disinfection
• Temperature and pressure • Steam penetration • Size of waste load • Length of treatment cycle • Chamber air removal	• Low investment cost • Low operation cost • Ease of biological testing • Creation of residue that is less hazardous than that of incineration	• Inability to change waste appearance • Inability to change waste volume • Lack of suitability for other waste types • Production of uncharacterised air emissions
Parameters influencing Microwave Disinfection	Advantages of Microwave Disinfection	Disadvantages of Microwave Disinfection
• Waste characteristics • Moisture content of waste • Microwave source strength • Duration of microwave exposure • Extent of waste mixture	• Ability to make waste unrecognizable • Significant volume reduction • Absence of liquid discharges	• High investment cost • Increased waste weight • Lack of suitability for other waste types • Potential to exposure workers to contaminated shredder • Production of uncharacterised air emissions
Parameters influencing Mechanical/Chemical Disinfection	Advantages of Mechanical/Chemical Disinfection	Disadvantages of Mechanical/Chemical Disinfection
• Chemical concentration, treatment, pH • Contact time with chemical • Waste and chemical mixing • Recirculation versus flow-through	• Significant waste volume reduction • Ability to make waste unrecognizable • Rapid processing • Waste deodorization	• High investment cost • Lack of suitability for other waste types • Production of uncharacterised air emissions • Need for chemical storage and use

Source: International Committee of the Red Cross 2011

Infectious agents can cause respiratory infections, genital infections, skin infections, meningitis, AIDS, Viral Hepatitis A, B and C. Radioactive substances can cause cancer, burn and skin irritation, headache, dizziness, and vomiting. Sharps pose a double risk in that they can cause injury and potential transmission routes for HIV and Hepatitis B and C from contaminated sharp. Pressurized containers may explode. Intoxication, burns and skin irritation, pollution of groundwater, surface water and the air, possibility of fire, poisoning can be as result of hazardous chemicals. Pharmaceuticals can result in the pollution of groundwater, surface water and air. Genotoxic waste is carcinogenic and mutagenic, skin or eyes irritation, nausea, headache or dermatitis (Koolivand *et al.* 2012, Mohankumar and Kottaiveeran 2012).

Examples of infections caused by exposure to medical wastes are also many. Hossain *et al* (2013) mention that there can be gastroenteric infections transmitted in faeces and /or vomit by Enterobacteria (e.g. *Salmonella*, *Shigella spp.*; *Vibrio cholerae*; *helminthes*), respiratory infections transmitted in inhaled secretions and saliva caused by *Mycobacterium tuberculosis*, measles virus, and *Streptococcus pneumoniae*. Eye secretions caused by Herpesvirus can cause ocular infections. Genital infections carried in genital secretions resulting from *Neisseria gonorrhoeae*; *herpesvirus*. Pus which contains *Streptococcus spp.* can cause skin infections. Anthrax caused by *Bacillus anthracis* can result from skin secretions. *Neisseria meningitidis* carried in cerebrospinal fluid may cause Meningitis. Blood and sexual secretions carrying Human Immunodeficiency Virus (HIV) can cause Acquired Immunodeficiency Syndrome (AIDS) while also Junin, Lassa, Ebola, and Marburg viruses can lead to haemorrhagic fevers and *Staphylococcus spp.* and *Candida albicans* can cause Septicaemia and Candidaemia respectively. Coagulase-negative *Staphylococcus spp.*; *Staphylococcus aureus*; *Enterobacter*, *Enterococcus*, *Klebsiella*, and *Streptococcus spp.* can result in Bacteraemia. Viral hepatitis A can be a result of Hepatitis A virus and viral hepatitis B and C be of Hepatitis B and C viruses carried in blood and body fluids (Hossain *et al.* 2013, 2011).

Titto *et al.* (2012) and Patwary *et al.* (2011) mention that many countries maintain stringent management systems for handling and safe disposal of medical waste to minimize the risk. In developed countries, technologies such as autoclaving and incineration are used for treatment and final disposal of medical waste. However, in developing countries,

medical waste has not received adequate attention, particularly when it is disposed of together with the domestic waste (Hossain *et al.* 2011). Effects of infectious waste and sharps are of primary concern since infectious and anatomic wastes together represent the majority of the hazardous waste, up to 15% of the total waste from medical activities. Sharps represent about 1% of the total waste but they are a major source of disease transmission if not properly managed (WHO 2011a). According to Chowdhury *et al.* 2011, it is common practice to use injections as a preferred treatment of diseases. Disease conditions where injections are frequently used include watery diarrhoea/dehydration, general weakness, skin infections, fever/pyrexia of unknown origin, road traffic accidents and assault cases, respiratory infections/pneumonia and abdominal pains/peptic ulcers.

There are numerous reasons behind popularity for the use of injections. These include the local beliefs about illness and concepts of efficacy, perceived severity of the disease (doctors' perspective) and doctors' belief that injections are more effective than oral medications. Sometimes, the use is based on the perceived seriousness of the diseases by the doctors often motivated them to use injections, a perception that serious conditions need serious and "powerful medication" and doctors' own quest to prove their superiority over other doctors through prescribing so called high-cost "powerful medications". In other cases, it may be due to lack of patient-provider communication, the sensitivity of the patients' condition and on the patients' demand. The demand may be as a result for desire to get quick relief: mostly derived from the perceptions that injections are the sure way to quick relief or a perception that injections are necessary in a good prescription or a notion to justify strong police cases against the offenders (in case of accident/assault incidences). Sometimes injections are used because of the pressure from hospital authority to use up the injections before their expiry dates and to release patients from the hospitals as quickly as possibly (affecting doctors prescribing behaviour to treat patients more aggressively with injections). In other cases, the prescribing and dispensing by the medical assistants/paramedics often has a tendency to over-prescribe injections because of prolonged absence of doctors from hospitals or in emergency case management in absence of doctors. Economic interests of pharmaceutical companies can also not be overlooked due to aggressive marketing/promotional activities and attractive gifts often on offer to the doctors and paramedics/medical assistants (Chowdhury *et al.* 2011).

Effects of chemical and pharmaceutical waste are of paramount importance since chemicals and pharmaceuticals account for about 3% of waste from medical activities (WHO 2011a). Medical science and the pharmaceutical industry continue to develop and produce new and more powerful drugs to treat a growing range of diseases for a steadily increasing global population. Medical products include a wide variety of vitamins, antibiotics, antipyretics, analgesics, anti-depressants and many more pharmaceutical products for both human and livestock consumption (Agamuthu and Fauziah 2011, Sasu *et al.* 2012, Voudrias *et al.* 2012). Not unexpectedly the pharmaceutical industry produces substantial volumes of waste, either directly or indirectly. These waste materials are generated both in the manufacturing process and by consumers who typically discard unused or outdated products. Pharmaceuticals appear as waste in production and distribution, as non-used medicine and in excreta from animals and humans. Post-consumer sources of pharmaceutical waste materials can be significant because they contain near-full strength concentrations of antibiotics, antiparasitics, hormones, analgesics, psychotropic medicines and many more natural and synthetic chemicals into the environment. Both manufacturing and post-consumer sources can lead to environmental degradation, particularly because many of the compounds in the waste streams are highly persistent and non-degradable in nature, and may be bio-accumulative. Thus, pharmaceuticals, like many other products, can be considered as both a major benefit to society and a public health liability if waste materials are not properly managed (Agamuthu and Fauziah 2011).

Genotoxic wastes account for less than 1% of waste generated from medical activities but their effects are similarly hard-felt (WHO 2011a). Medical waste incinerators can emit toxic air pollutants if incinerators are not properly designed and operated. Pollutants include particulate matter, acid gases, trace metals, products of incomplete combustion (PIC) and polynuclear organic matter (Dioxins). Among the latter compounds, Polychlorinated dibenzo-dioxins (PCDDs) / Polychlorinated dibenzo-furans (PCDFs) in exhaust gases and incineration ashes are of major concern. PCDDs/PCDFs are two series of aromatic polycyclic hydrocarbons which form a group of 210 different compounds consisting of 135 PCDF and 75 PCDD. Congeners containing chlorine in 2,3,7,8 positions have been identified as the most toxic to exposed organisms. So target substances are reduced to 7 PCDD and 10 PCDF (Haylamicheal and Desalegne 2012, Vilavert *et al.* 2012). Nevertheless, not all 2,3,7,8 chlorinated PCDD/PCDF have the same toxicity, 2,3,7,8 Tetrachlorodibenzo-p-

dioxin (TCDD) being catalogued by the WHO as a human carcinogenic (Du *et al.* 2013, Ragazzi *et al.* 2013, Yan *et al.* 2012, WHO 2011b).

Members of the PCDD family bioaccumulate in humans and wildlife because of their lipophilic properties, and may cause developmental disturbances and cancer. Dioxins occur as by-products in the manufacture of some organochlorines, in the incineration of chlorine-containing substances such as PVC (polyvinyl chloride), in the chlorine bleaching of paper, and from natural sources such as volcanoes and forest fires (Yan *et al.* 2012). Exposure to high levels of dioxins in humans causes a severe form of persistent acne, known as chloracne (Vilavert *et al.* 2012). High occupational or accidental levels of exposures to dioxins have been shown by epidemiological studies to lead to an increased risk of tumours at all sites. Other effects in humans (at high dose levels) may include: developmental abnormalities in the enamel of children's teeth, central and peripheral nervous system pathology, thyroid disorders, damage to the immune systems, Endometriosis and Diabetes (WHO 2011b).

Radiation hazards of radionuclides arising from nuclear plant facilities are well known (Ambashta and Sillanpää 2012). Radioactive wastes accounts for less than 1% of waste generated from medical activities (WHO 2011a). The use of radiation sources in medical and other applications is widespread throughout the world. Occasionally, the public is exposed to radioactive waste, which originates from radiotherapy treatment (Gilley and Holmberg 2013) that has not been disposed of properly (Hinton *et al.* 2013). Serious accidents have been documented in Brazil in 1988 (where four people died and 28 had serious radiation burns), Mexico and Morocco in 1983, Algeria in 1978 and Mexico in 1962 (Mihailidou *et al.* 2012). The most recent nuclear disaster was triggered when the Tohoku earthquake and tsunami occurred off the Pacific coast of Japan in March 2011 (Obana *et al.* 2012) and caused the Fukushima Dai-ichi nuclear power plant accident (Watanabe *et al.* 2012). The collapse of the Fukushima Dai-ichi Nuclear Power Plant caused a massive release of radioactive materials to the environment but until now no prompt and reliable system for evaluating the biological impacts of this accident on animals has not been available (Hiyama *et al.* 2012, Smith *et al.* 2012). Before the earthquake and tsunami that preceded the nuclear accident, there were eight hospitals and 17 nursing care facilities located within a 20 km radius of the Fukushima Dai-ichi Nuclear Power Plant. The estimated numbers of hospital inpatients and elderly people in nursing facilities at that time were about 1240 and

980, respectively (Tanigawa *et al.* 2012). The Japanese Government has not reported any deaths as a result of this but the United Nations (UN) report would only be available in May 2013 (Richter 2012).

The International Atomic Energy Agency (IAEA) and the Canadian Nuclear Safety Commission (CNSC) have reported that the combined effects of the earthquake and tsunami devastated the coastal area, exacting a dreadful toll: almost 20 000 lives were lost, over 8 000 people remain missing, more than 679 000 homes were destroyed or damaged and about 560 square kilometres of land flooded. There are numerous risks associated with medical waste and health hazards could result in injuries and accidents. There is a risk of injuries related to medical waste handling and carrying by waste haulers and/or cleaners. For example, there could be a cut-injury punctured wound, laceration, strain and sprain of the joint of limbs and backache due to load hauling (Kakizaki *et al.* 2011). According to Agamuthu and Fauziah (2011), Sasu *et al.* (2012) and Voudrias *et al.* (2012), there could be hands cut due to handling broken glasses. One could be injured by a needle resulting in fingers being permanently damaged/ becoming curved. Quite often right hands become paralyzed by the injury of a needle. Sometimes, two legs become paralyzed due to injury by a needle. Risks may also include skin diseases on legs and hands/ body, pus due to injury and ulcers on legs. Again sharps, which include syringes and needles, have the highest disease transmission potential amongst all categories of medical waste. Almost 85% of sharp injuries are caused between their usage and subsequent disposal. More than 20% of those who handle them encounter 'stick' injuries. According to Chowdhury *et al.* (2011) injuries from needle-stick and sharps occur frequently in developing countries, and that safer disposal facilities and routine hepatitis B vaccine should be adopted.

Infectious hospital waste represents only a small part of total medical waste; yet, because of ethical questions and infection risks, it is a focal point of public interest. Infectious waste contain different kinds of pathogens or organisms (see Table 4) that is potential for infection or disease if it is not properly disposed (Agamuthu and Fauziah 2011, Sasu *et al.* 2012, Voudrias *et al.* 2012). Table 4 shows few examples of different pathogens and diseases caused by them. Infected hospital waste can transmit diseases, especially if it finds portals of entry. There is strong epidemiological evidence that the main concern of

infectious hospital waste is the transmission of HIV/ AIDS virus and more often of Hepatitis B or C virus (HBV) through injuries caused by syringes contaminated by human blood.

Table 4 Examples of different pathogens and diseases caused by them

Pathogen	Disease caused
Bacterial	<i>Tetanus</i> , Gas gangrene and other wound infection, Anthrax, Cholera, Other diarrhoeal diseases, Enteric fever, <i>Shigellosis</i> , TB, Plague.
Viral	Various hepatitis, <i>Poliomyelitis</i> , HIV-infections, HBV, some STDs, Rabies.
Parasitic	<i>Amoebiasis</i> , <i>Giardiasis</i> , <i>Ascariasis</i> , <i>Ankylostomiasis</i> , <i>Taeniasis</i> , <i>Echinococcosis</i> , Malaria, <i>Leishmaniasis</i> , <i>Filariasis</i> .
Fungal	Infections Various fungal infections like <i>Candidiasis</i> , <i>Cryptococcoses</i> , <i>Coccidiomycosis</i> .

Source: Centre for Disease Control and Prevention (CDC) 2012

Other than these, there is potential risk of Tuberculosis / Throat infection, Typhoid, Dysentery, Diarrhoea, Bacterial / Viral diseases, ARV (Rabies), VDRL (Sexually transmitted disease), Urinary Tract Infection (UTI) / infection during Caesarean Section (C/S), and Leprosy as the pathological laboratories do all these analysis to diagnose the diseases (Kakizaki *et al.* 2011).

Hazardous medical waste, while largely ignored, poses risk to workers handling them (Aghapour *et al.* 2013). Hazardous medical waste consists primarily of chemicals and discarded cytotoxic drugs. The pathological laboratories of medical centres examine blood, stool, urine, and sputum. The chemicals used for the staining and preservation of slides and for the sterilization and cleaning of equipment and surroundings are potentially harmful to the laboratory technician and the environment. Most of the chemicals are poured down the sink and drain out next to the clinic. Children, adults, and animals all have the potential to come into contact with these chemicals. Xylene, phenol, methylene blue, hydrochloric acid, chlorine and carbol fuchsin are all used, and some can have very damaging effects (Lekwot *et al.* 2012). Other than these, there are a large number of chemicals also used in different diagnosis and treatment (e.g. chemotherapy). Some probable hazardous chemicals and carcinogens or pose other health risks and effects are acid gases (e.g. HCl, NO_x, SO₂), which have acute effects such as eye and respiratory irritation and may enhance toxic effects of heavy metals. Carbol Fuchsin used in the fixing of sputum slides may be readily absorbed and can cause severe burning if brought in contact with eyes/skin/lungs. Its inhalation

results in chest pains, increased heart rate, coughing, nose and throat irritation, convulsions and eventually death. Chemotherapy and neo-plastic chemicals are hazardous and toxic and are potentially carcinogenic. Dioxins may be made from chlorine made material (e.g. PVC) and these together with formaldehyde are animal carcinogen and considered human carcinogen as well. Glutaraldehyde, a fixer or developer in photographic X-ray) is hazardous and could pose several health risks (Lekwot *et al.* 2012).

Heavy metals (Mercury, Arsenic and Zinc, for example) used in instruments, treatment and medicine industries are neurotoxic. Women and children are most vulnerable and as heavy metals could either have carcinogenic, mutagenic, teratogenic effects. Heavy metal exposure leads to pneumonitis, bronchitis muscle tumour, irritability and gingivitis. Usually heavy metals enter the food chain and become bio-amplified. In humans these metal can cause kidney and liver disorders, weaken bone structure, damage central nervous system and cause blindness and lead to death. Hydrochloric acid used in the fixing of sputum slides may cause burning sensation if brought in contact with eyes/skin. Methylene Blue, used in fixing of blood and sputum slides can cause damage if brought in contact with eyes, skin, clothing Phenol (i.e. disinfectant, sterilizer) can cause severe burning of eyes, skin and lungs if in contact, can seriously affect lungs and respiratory system if inhaled (pulmonary oedema, lung inflammation) and is potentially fatal. Ingestion of phenol can cause nausea, vomiting, gastrointestinal irritation and bleeding while over exposure can lead to kidney and liver damage. Polychlorinated biphenyls (PCBs) are harmful to fish and other aquatic forms of life because they interfere with reproduction. PCBs produce liver ailments and skin lesions in human. In higher concentration they can damage nervous system and are suspected carcinogens. Xylene which is used in the removal of seederwood oil for TB slides when its vapours are inhaled can cause: headaches; euphoria; light-headedness; dizziness; drowsiness and nausea while over-exposure can cause irregular heartbeat, fainting and eventually death (Lekwot *et al.* 2012).

2.13 Risk of Medical Waste to the Environment

Waste generated from medical activities can result in negative impacts to the environment if there is inappropriate treatment and disposal (Musee 2011, Titto *et al.* 2012, Zhang *et al.* 2011a). Applying an organized medical waste management system is necessary in any community to subdue environmental hazards from contamination by these types of

waste. Like any other waste management system, waste reduction is the first step in medical waste management. Thus, applying a source reduction system in hospitals through training personnel is very important. The amount of medical waste generated depends on the factors which may be different not only in various countries, but also between different cities of a country. Composition of medical wastes may also be different (Tauseef *et al* 2013, Ferdowsi *et al.* 2012). There are several environmental concerns with respect to improper disposal of bio-medical waste management: spread of infection and disease through vectors (fly, mosquito) which affect the in-house as well as surrounding population. One is the spread of infection through contact/injury among medical/non-medical personnel and sweepers/rag pickers, especially from the sharps (needles and blades). Another is the spread of infection through unauthorised recycling of disposable items such as hypodermic needles, tubes, blades, bottles and reaction due to use of discarded medicines (Pasupathi *et al.* 2011). Idoko *et al.* (2012) and Tan and Xiao (2012) determined that heavy metals leached into the soil adversely affected the environment and that the consumption of food crops contaminated with heavy metals is a major food chain route for human exposure. Earlier studies conducted elsewhere on standing food crop samples including radish (*Raphanus sativus* L), maize (*Zea mays*), green cabbage (*Brassica juncea* L), spinach (*Spinacia oleracea* L) (Kutu *et al.* 2011), cauliflower (*Brassica oleracea* L), turnip (*Brassica napus*), and lettuce (*Lactuca sativa* L) showed that soils and all food crops studied were contaminated with Cd, Cr, and Ni, and partially and/or totally exceeded the permissible limits set by the Chinese State Environmental Protection Administration (SEPA) and the World Health Organization (WHO) (Khan *et al.* 2008).

There are several environmental impacts associated with the improper disposal of medical wastes. Pollutants from medical waste (e.g. heavy metals and PCBs) are persistent in the environment leading to the accumulation of toxic chemicals within soil (proximity to agricultural fields, humans, soil organisms, wildlife, cattle). Ground water contamination, decrease in water quality, bio-accumulation in organism's fat tissues, and biomagnifies through the food chain are among the impacts (Vilavert *et al.* 2012). Repeated and indiscriminate application of chemicals over a long period of time has serious adverse effects on soil microbial population thereby reducing the rate of decomposition, and generally lowering the soil fertility. Pathogens lead to long term accumulation of toxic substances in the soil such that specimens collected for analysis have the potential to cause

disease and illness in man, either through direct contact or indirectly by contamination of soil, groundwater, surface water, and air. Wind-blown dusts from indiscriminately dumping also have the potential to carry hazardous particulates. With domestic animals being allowed to graze in open dumps, there is the added risk of reintroducing pathogenic micro-organisms into the food chain. Impacts may lead to public nuisance (e.g. odours, scenic view, block the walkway, aesthetics). Improper sterilization of instruments used in the labour room may cause infection to mother and child. Combination of both degradable and non-degradable waste increase the rate of habitat destruction due to the increasing number of sites necessary for disposal of wastes (degradation of habitat). Plastic-bags, plastic containers, if not properly destroyed may contaminate the soil and also reduce the chance for water percolation into the soil during precipitation. Open air burning does not guarantee proper incineration, and releases toxic fumes (dioxin) into the atmosphere from the burning of plastics i.e., Polychlorinated biphenyls (PCB's) (Geng *et al.* 2011, Vilavert *et al.* 2012).

2.14 Risk of Medical Waste to People and Animals

In animals dioxins cause a wide variety of toxic effects. In particular TCDD has been shown to be teratogenic, mutagenic, carcinogenic, immunotoxic and hepatotoxic. Furthermore, alterations in multiple endocrine and growth factor systems have been reported. The most sensitive effects are caused at body burdens relatively close to those reported in humans. Among the animals for which TCDD toxicity has been studied, there is strong evidence for teratogenicity (birth defects) (in rodents, including rats, mice, hamsters, guinea pigs, birds and fish), cancer (including neoplasms in the mammalian lung, oral/nasal cavities, thyroid and adrenal glands, and liver, squamous cell carcinoma and various hepatocarcinomas) in rodents and fish. There is also hepatotoxicity in rodents, chickens and fish, endocrine disruption (in rodents and fish) and immunosuppression (in rodents and fish). The LD50 of dioxin also varies wildly between species with the most notable disparity being between the ostensibly similar species of hamster and guinea pig (Khan *et al.* 2008).

Heavy metal accumulation in soils and plants is of increasing concern because of the potential human health risks. This food chain contamination is one of the important pathways for the entry of these toxic pollutants into the human body. Heavy metal accumulation in plants depends upon plant species, and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil-to-plant transfer factors of the

metals. Vegetables cultivated in wastewater-irrigated soils take up heavy metals in large enough quantities to cause potential health risks to the consumers. The consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the body that are further responsible for decreasing immunological defences, intrauterine growth retardation, impaired psycho-social faculties, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates (Khan *et al.* 2008). Improper disposal practices of medical waste affects the people who come in direct contact with it. Waste piles also attract a variety of disease vectors, including mosquitoes and flies and can cause environmental pollution, unpleasant odours, and growth of insects, rodents and worms; it may lead to transmission of diseases like typhoid, cholera, HIV, Tuberculosis, Hepatitis B and C through injuries from sharps contaminated with human blood (Muduli and Barve 2012, Arora and Agarwal 2011).

2.15 Medical Waste Treatment in South Africa

Population growth due to unplanned urbanization with neglect towards environmental pollution control in general, and the management of solid waste and medical waste in particular, has been a cause of serious concern, especially in the developing countries (Agamuthu 2013, Rogers and Brent 2006). The ineffective management of medical waste leads to negative environmental impacts (Titto *et al.* 2012). Hospitals are one type of complex institution which is frequented by people from every walk of life within society with no distinctions between age, sex, race or religion (Nema *et al.* 2011). The introduction of new materials with changing consumption patterns and lifestyle, increased population and human activities, especially in urban areas, has resulted in exponential increase in the volume of solid waste generation resulting into breakdown of traditional and sustainable systems of waste management cycle (Titto *et al.* 2012). Medical waste management continues to present an array of challenges for developing countries (Manga *et al.* 2011), and South Africa is no exception (Abor 2007, Rogers and Brent 2006).

In South Africa, the problem of waste from hospitals has been recognised by the concerned agencies and various government regulations have been framed to systematise its implementation. There is generally an emphasis towards modern hospital waste practices that reduce risks of hazardous wastes to humans or to the environment by treating the waste first before being disposed of in a landfill (Chai *et al.* 2013). Figure 3

shows how waste is treated and disposed of in South Africa according to the National Waste Management Strategy Implementation project (NWMSI) of the DEAT (2005) while Figure 4 shows a model in the study area. So far over 90% of South African toxic hospital waste is incinerated, while hospital waste that is regarded as non-toxic is either dumped openly or landfilled. In most hospitals, the incinerators that are used still use coal as the main source of heat with significant quantities of hazardous pollutants such as dioxins, furans and heavy metals like cadmium (Cd), mercury (Hg), and lead (Pb). Where the medical facility has an on-site incinerator, medical waste is treated at this level and residue ash transported to specialized landfill sites (Nemathaga *et al.* 2008). The two models are not similar in that whilst they both consider treatment of these MRW the DEAT does not mention by which method this should be accomplished.

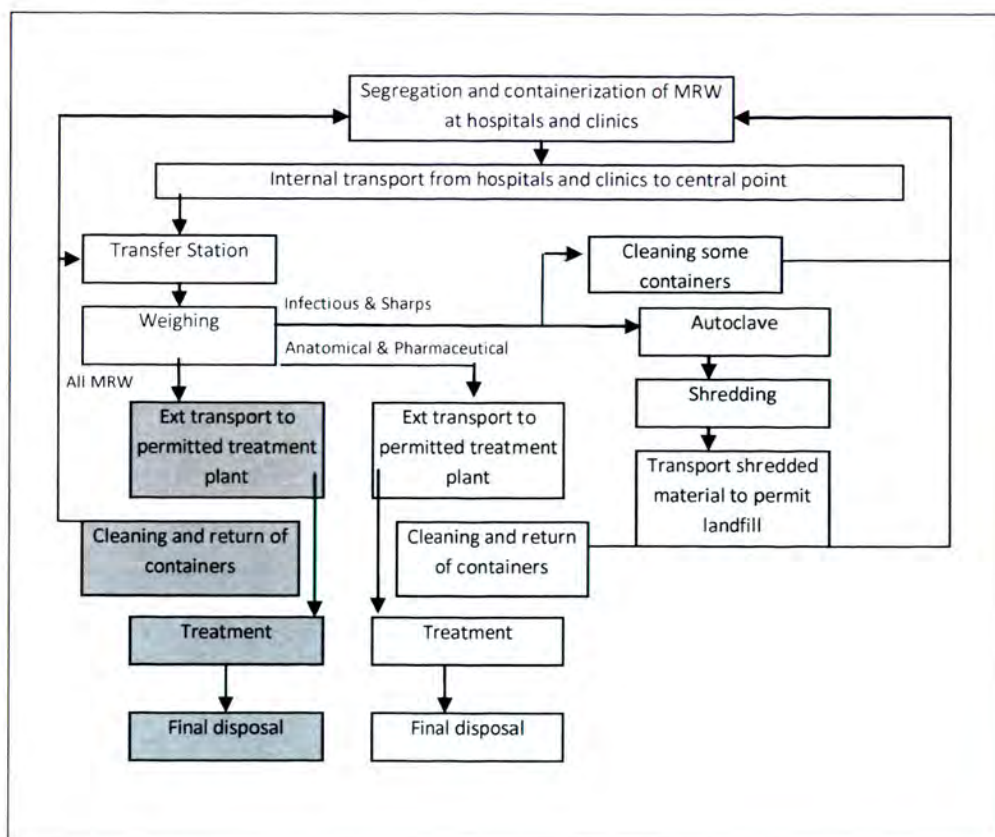


Figure 3 Proposed National Medical Waste Chain (DEAT 2005: 15)

Figure 4 specifically mentions the method to be either incineration and/or autoclaving. The other dissimilarity is that while both models put emphasis on disposal of the residue, in Figure 4 disposal could either be in a land-fill or in an open-dump. In

developing countries sanitary land filling is the preferred method of solid waste disposal in most situations due to its low cost, minimal environmental impacts when designed and operated correctly, and effectiveness in controlling health risks (Agamuthu 2013, Alslaibi *et al.* 2013, Diaz and Otoma 2013, Hatami-Marbini *et al.* 2013, Özkan 2013, Siddiqui *et al.* 2013, Zaman and Lehmann 2013). Landfills must have high performance bottom and sidewall liner systems to prevent leachate from escaping the landfill and contaminating surrounding ground water. To minimize water infiltrating the refuse and creating leachate, drainage systems and cover systems must be designed and built to meet specified performance standards (Hossain *et al.* 2011, Nas and Bayram 2011, Weber *et al.* 2011, Sasu *et al.* 2012, Titto *et al.* 2012).

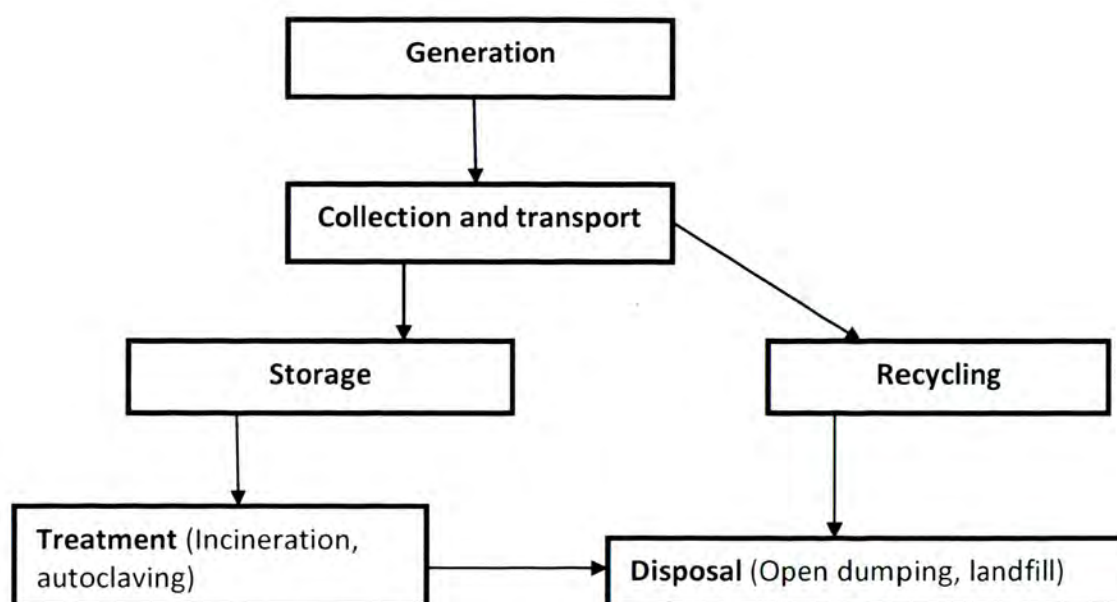


Figure 4 Medical Waste Chain in the Study Area

Dursun *et al.* (2011b) suggest that benefiting from the literature on the assessment of medical disposal alternatives and discussions with the experts, economic criteria, environmental criteria, technical criteria, and social criteria, and their related sub-criteria are identified as the evaluation attributes in a hierarchical framework. Determining the best medical waste treatment alternative requires comprehensive considerations of costs to be incurred, environmental considerations to bear in mind (i.e. noise and odour from the facilities) and technically sound options as to the release of by-products (i.e. reliability,

volume reduction, need for skilled operators and impact on occupational hazards) and also compliance with environmental adaptability from a social aspect.

2.16 System Indicators and Indexes

The most widespread way to evaluate sustainability is the use of indicators and indexes. Indicators enable systematic performance evaluation and make it possible to present information for decision makers in the most suitable form. Continuously measured and calculated indicators allow tracking of longer-term sustainability trends from a retrospective point of view. Analysis of these trends allows decision makers to make short-term projections and relevant decisions for the future (Arora and Agarwal 2011, Stasiskiene *et al.* 2011). An effective indicator should be efficient (i.e. easily measured and analysed with existing data), effective (i.e. sensitive to change and clearly linked to causative factors), economically and logistically feasible (i.e. already being measured) and reliable (i.e. accurate and continuous). According to Arora and Agarwal (2011), Godfrey and Scott (2011), and Stasiskiene *et al.* (2011), the main criteria for evaluating sustainable waste management are necessary. First there has to be environmental desirability as this refers to whether the waste management options can safeguard public health and the environment. Secondly, there should be economic optimization which refers to the cost-effectiveness of each waste management option in use and the economic soundness of the waste management strategy. Thirdly, there should also be social acceptability and equity which will ensure as to how receptive and supportive the local community is to waste management options in use and the effective use of the partnership approach in waste management. Finally, administrative diligence should be in place so as to oversee whether the administrative capacity is adequate to ensure that good measures and policies can be carried out continuously and be sustained in the long term.

To assess sustainability of a medical management system, including waste generation, export and import, and disposal, a set of innovative indicators and indexes is required. Many attempts have been made to designate the indicators for solid waste management (Tirado-Soto and Zamberlan 2013), but the situation with medical waste is quite the opposite. According to Stasiskiene *et al.* 2011, the key work in defining medical waste indicators was done by Peterson and Granados (1999). They determined the medical waste indicators for national decision makers as a useful tool to help them make environmentally sound

decisions leading to the effective management of medical waste. Generally, indicators can be used not only for decision makers but also for municipalities, agencies, the public, and so on. Evaluating the sustainability appraisal of medical management is quite a new and challenging issue. Sustainability indicators are viewed from an environmental point as ratios by considering the hazardous waste generated per year, accepted at landfill proportional relative to the total hazardous waste, hazardous waste exported proportional to the total hazardous waste and hazardous waste accepted at hazardous waste treatment centres as against exported hazardous waste. Economically, consideration is placed on hazardous waste generated per Gross Domestic Product (GDP). Consideration is also placed on hazardous waste disposal of medical waste per ton as well as the net cost of operating and maintaining hazardous waste treatment facilities. The cost of exporting waste per ton is also compared with cost of storing that hazardous waste as well as hazardous waste generated per employee. Socially, hazardous waste is considered per capita, level of public acceptance, level of public participation in planning and implementation and as well as hazardous waste generated per employee (Stasiskiene *et al.* 2011).

After theoretical and practical research, a set of indicators was developed for sustainable medical waste management. The main criteria for development of indicators were the NEMA Amendment Bill 2007 for management of waste including hazardous materials, as well as data and perspectives on medical waste generation. The selected indicators cover the core areas of sustainable development: environmental, economic, and social development. Measuring environmental sustainability in a medical waste management system is not complicated - as is environmental sustainability in general, it can be defined as rational resource consumption and reduction in environmental pollution. A suggested set of environmental sustainability indicators for medical waste contain an indicator of the amount of medical waste generated per year. Medical waste generation has a direct impact through exposure on health and the environment. In general, long-term exposure is required before the expression of harmful effects. Reduced generation of medical waste may indicate either reduced industrial activities in a country; introduction of cleaner production in the industrial processes; or changing patterns in consumers' habits, which implies savings in the use of energy and raw material as well as improving protection of landscapes. The introduction of environmentally sound management systems

for medical waste implies reduction in risks to health and environment due to lesser exposure to medical waste. If diverse categories of generated wastes are examined, this indicator can specify the nature of industrial activities functioning in a country. For example, the amount of hospital wastes generated per year can indicate the size of population and the percentage of this population treated in medical care units.

One indicator can show the ratio of medical waste accepted at landfills to the total amount of medical waste. This indicator reveals the amount of medical waste disposed of by the least favourable option of waste hierarchy. The lower proportion means higher sustainability of medical waste management system. It could also be the ratio of medical waste exported to total medical waste amount. This indicator is related to the amount of medical waste and shows the availability of export and import disposal options in the country. This indicator also shows the demand for export to recycle or use medical waste as secondary raw material and provides a measure of current medical trade practices. Another one could be the ratio of exported medical waste to medical waste accepted at medical waste treatment centres. This indicator shows the amount of exported medical waste and the possibilities to manage waste in the country. The reason for medical waste export can be economic (the price for treatment is too high for small quantities of different medical waste flows), technologic (no required treatment technology is available), political, and so forth (Stasiskiene *et al.* 2011).

Economic indicators are related to the monetary expression of medical waste management system. They can contain an indicator of medical waste generated per Gross Domestic Product (GDP). GDP is a basic economic growth indicator and measures the level and extent of the total economic output. Growth in the production of goods and services is a basic determinant of how the economy fares. Through the relation of total production to medical waste generation, the extent to which the industry and province contributes to generation of medical waste can be measured. Three additional benefits—increase in economic vitality, conserved valuable resources and increased efficiency—can be also evaluated. Economic indicators can include the cost of medical waste disposal per ton, net cost of operating and maintaining medical waste treatment facilities and the ratio of cost of medical waste exported ton to cost of storage of one ton of medical waste. These indicators relate expenditures of medical waste treatment with the amount of generated medical waste and reveal the monetary value of medical waste generation. At the moment, it is

difficult to find information about expenditures on medical waste treatment. But if the demand that treatment centres provide the information about their costs were included in the national laws, it would be possible to evaluate the best method of medical waste treatment. In addition, all these indicators will reveal the benefit of reducing medical waste generation. The indicator—the ratio of cost of MRW exported ton to cost of storage of 1 ton of medical waste shows what is more profitable: to store medical waste until the destructor is built, or to export medical waste to other countries for disposal. This indicator can be used to trace separate medical waste materials. Medical waste generated per employee. Distribution of industrial activities varies within each region and province. By relating the waste quantities to the number of employees, one should be able to compare each region by medical waste generation in industries. Medical waste generated per employee is an intermediate indicator that connects economic and social aspects of sustainability (Stasiskiene *et al.* 2011).

A social aspect in medical waste management in broad terms is ethical behaviour of the waste management system toward society's well-being. Aspects concerning the problems of public acceptance, public participation in planning and implementation, consumer behaviours, and changing value systems are no less important than the environmental or economic aspects in waste management research and decision making (Dursun *et al.* 2011a). The social goal of sustainability is to achieve the well-being of both the human system and the ecosystem. In this context, the concept of sustainability becomes much wider than just a means for environmental protection. A social sustainability set contains an indicator of medical waste generated per capita. The most common and easiest way to measure medical waste is medical waste generated per capita. This indicator shows the progress being made toward the target of reducing the amount of medical waste per person. This indicator can be used to show hazardous medical waste amount generated per person per year. In such a case, the bigger amount shows that people use more medical waste in their homes (batteries, solvents, paints, cleansers). In an industry sector (if the population in the country remains stable or differs slightly) the indicator shows that more MW is generated. It also depends on economic growth, import, export, and other factors. A social indicator can be public acceptance of medical waste management plans and actions, and public participation in planning and implementation of the medical waste management system. These indicators reflect the public involvement in the medical waste management

system (Stasiskiene *et al.* 2011). The participation of society is very important in sustainable development, because people are the users of this management system. The whole medical waste management system has to work properly to ensure the safety of the society, good living conditions, and social equity. At the moment, it is difficult to measure public acceptance of medical waste management plans. The way to do that is to arrange questioning sessions and examine a representative selection of respondents. Measuring public participation in planning and implementation of medical waste management system is difficult as well.

The system of the indicators will reveal the state of sustainability of medical waste management in the country and foster implementation of technical and policy innovations. The system can be applied to other countries and become an efficient tool in comparing sustainability of medical waste management systems in different countries and can be used by national decision-makers, waste managers, local municipality representatives, and other stakeholders (Achillas *et al.* 2013, Hatami-Marbini *et al.* 2013, Tirado-Soto and Zamberlan 2013, Faisal *et al.* 2011).

2.17 Summary

The chapter has reviewed global trends in medical waste management practices. Literature shows that most studies reveal repeated themes of (a) deficiencies in training, health and safety measures for the staff, (b) limited budget for the waste management, (c) gaps within the management structure as well as (d) poor legislation, planning and guidance at the country level. Most researchers concluded that management practices of such waste, especially the hazardous portion, represent a challenge in their countries due to deficiency in waste generation data and/or gaps in the management framework. In addition, absence of a medical waste management plan at the country level and unavailability of suitable treatment and disposal options can further hinder the waste management efforts. The current research will try to address issues relating to deficiencies in training, health and safety measures for the staff and advocate for better medical waste management practices in the area by addressing the importance of segregation at source, use of appropriate and well-labelled containers, medical waste conveyance on-site, encouragement on proper use of personnel protective gear and the overall need for training of personnel. The next

chapter deals with the materials and methods undertaken to investigate the stated problem.

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

This chapter deals with methodology followed to investigate the stated problem. It considers methods employed to determine medical waste management practices in the study area, techniques used, their justification and materials used to bring about the desired results.

3.2 The Study Area

The primary study area is the north eastern Free State, which is one of the nine provinces of South Africa. It is in this section of the country that medical facilities that were investigated are located (Figure 5). The map of Free State shows the location of the towns in which the medical facilities are found as given in Table 5.

Table 5 Medical Facilities

Local Municipality	Town	Name of Facility
Maluti A Phofung	Phuthaditjhaba	Mofumahadi Mmanapo Mopeli Regional Hospital
		Elizabeth Ross Hospital
		Thebe Hospital
Dihlabeng	Bethlehem	Dihlabeng Regional Hospital
		Phekolong Hospital
		Medi – Clinic (Hoogland) Private Hospital
		Corona Sub Acute Hospital
Mantsopa	Ladybrand	Nkhono Mantsopa Hospital
Nketoana	Reitz	Nketoana Hospital
Phumelela	Vrede	Phumelela Hospital

Other related factors (see Appendices G – I) that have a bearing on the management of medical waste could be levels of education, gender, ethnic group, racial make-up (i.e. 95.17% are Black and 4.16% are White with Coloured and Indian/Asian making up the rest) and language groups since the respondents came from a much diversified population which influence views on waste management policy, practices and their attitudes.

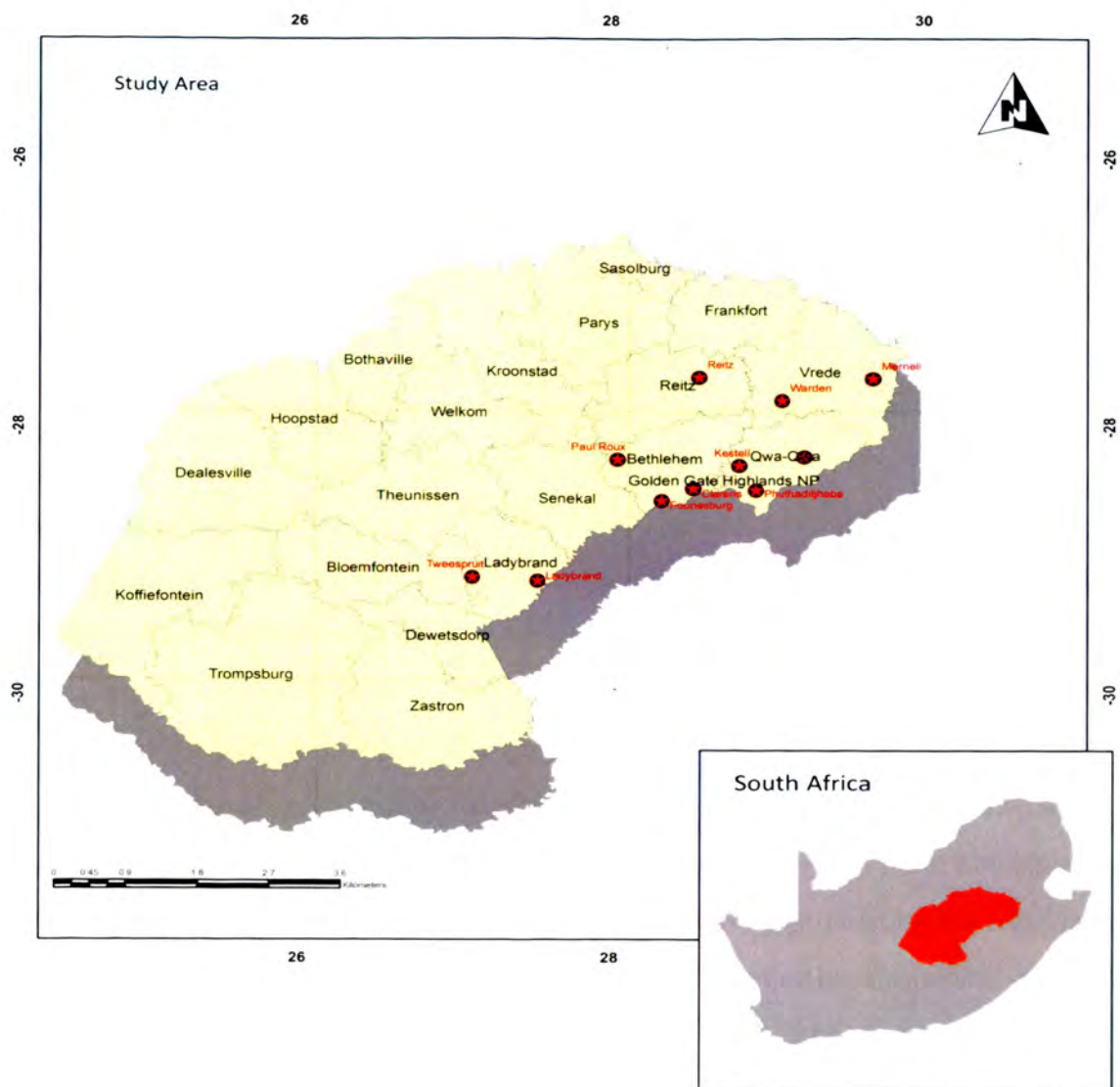


Figure 5 The Map of the Free State, South Africa

The population in the study area is around 800 000 inhabitants, comprising of 54% females and 46% males (Statistics South Africa 2012). The largest population resides in the Maluti-A-Phofung local municipality (i.e. 46%) followed by Dihlabeng and Setsoto local

municipalities at about 15% each. Geography by language is dominated by Sesotho (i.e. 81%) followed by IsiZulu (i.e. 12%) then Afrikaans at 4%, English, IsiXhosa, SiSwati, Setswana, Sepedi, IsiNdebele, Xitsonga, Tshivenda and Other making up the rest. All of these medical facilities were moderately accessible through a series of secondary roads of some sort. Their accessibility in terms of their expected service was somewhat compromised by their location. Traffic flow to a number of these medical facilities could be a problem in an event of a major disaster occurring in the area.

3.3 Research Design

The research design was centred on field surveys made up of site observations and measurement. This was followed by the administration of interviews with health authorities in a selection of ten hospitals in the north eastern Free State. This was reinforced with secondary data from official sources at the provincial and national levels. A structured interview (Appendix A) was developed after literature search and review. First level respondents were doctors, nurses, and hospital staff related to waste generation and handling. Second level respondents were hospital authority, medical services provider as well as all the relevant institutions and organizations involved in health care services. This interview was designed to suite four categories of personnel associated with medical care facility settings, i.e. Head of Hospital, Head of departments, Supervisors and Medical waste handlers. A pilot survey was also carried out by distributing and conducting the interview to five personnel from all the four categories. Informal consultations with medical personnel were also done. The respondents were asked to indicate their views on waste management policy, practices and their attitude related to the issue. Opportunity was also given to give details regarding certain questions that were asked. The research followed the outline shown in Figure 6.

3.4 Choice of Instruments

Two instruments, structured questionnaire and participant observation strategy / discussions were adopted in this study. The interviews were administered to the pre-determined medical personnel. The existing medical waste management practices and policy with respect to collection, storage, transportation and final disposal were evaluated against health guidelines. Information regarding staff strength, services available, number of

beds, average bed occupancy rate, and profile of medical waste handlers were collected through interviews; others were quantities and waste type produced.

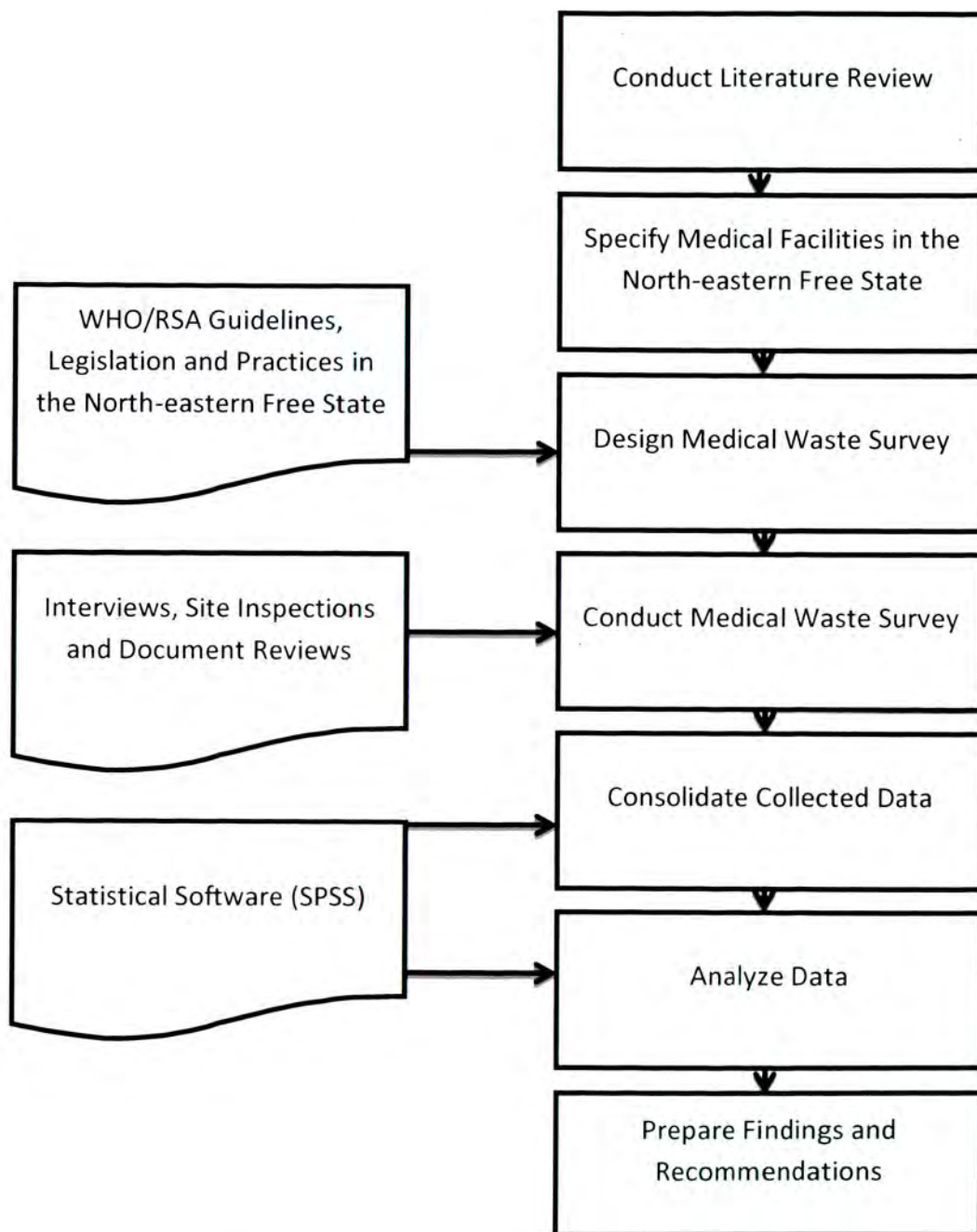


Figure 6 Flow-line of the research design.

The discussion was organized to obtain additional information from respondents and heads of departments and units as well as use the responses to validate some of the results

from the in-depth interview. In total, 139 medical personnel were interviewed. The criteria used for classifying waste management practices included items such as: using a colour-coded container for segregation of medical waste; appropriate use of colour-coded containers for segregation; quality of on-site transportation of medical waste; use of safety boxes for sharp waste; using of protective measures by medical waste workers; training of medical waste workers; method and quality of on-site treatment; final treatment quality and disposal method. The interviews were designed in such a way as to enable respondents to indicate waste types generated and disposal methods. The interview was structured to generate data on the following:

- I. Various sources of wastes in the hospital.
- II. Type of waste collected and handled.
- III. Safety of personnel and personnel handling waste.
- IV. Adequacy of the protective wear provided.
- V. Current waste handling methods/procedures.
- VI. Transportation, treatment, and waste disposal methods/ procedures.
- VII. Existing waste management system.
- VIII. Awareness of hospital staff on waste management.

3.5 Validity

A pilot study of 20 test interviews was conducted at a medical facility in Phuthaditjhaba. From the feedback, ambiguities in the questions were eliminated. The Interview instrument was validated. Self-administered interview was used, including 26 questions about the respondents' knowledge, attitudes and practices (KAP) and personal and professional variables addressing similar issues to those by Jabbari *et al.* (2012) and Madhukumar and Ramesh (2012). The use of the pilot study also made it possible for the researcher to establish whether the individual questions actually measured the target variable(s) of interest. In so doing, the questions ensured reliability.

3.6 Population

The number of medical establishments was selected on the basis that they are found in the north-eastern Free State and that they are hospitals. According to DEAT (2005: 12), there are 50 public hospitals with a combined 10 016 bed capacity and 21 non-public

hospitals with a combined 1 951 bed capacity that produce 807 856 kg/annum and 618 116 kg/annum waste, respectively. A representative sample (i.e. 10 hospitals) was considered following Patwary and Sarker (2012). This represented 14% of the population of hospitals in the province. Participants from different levels within each organization were selected using a combination of purposive and authoritative sampling approaches (Patwary and Sarker 2012, Patwary *et al.* 2012).

3.7 Unit of Analysis

The unit of analysis selected was each individual hospital irrespective of the size. This was done irrespective of whether a particular medical establishment was: (1) Hospital (large public or private establishments with many departments and more than one building) or (2) clinic (smaller, private, establishments in one building, or a portion of a building, with no outpatient service) or (3) pathology/diagnostic centre (small private establishments with no patient beds or overnight accommodation for patients) (c.f. Patwary and Sarker 2012).

3.8 Specification of Variables

Specification of variables (Table 6) depends on all aspects that lead to generation of medical waste. Medical waste generation depends on several factors including the size of the healthcare facility, occupancy rate of hospital beds, medical waste segregation system, location of the medical facility and type of services provided (Eker and Bilgili 2011).

3.9 Sampling Procedures

The number of medical establishments was selected on the basis that they are found in the north-eastern Free State and that they are hospitals. Ten hospitals in the study area were randomly selected as representative of medical institutions. A stratified random sample of 139 interviews with staff members was considered following Patwary and Sarker (2012), and participants from different levels within each organization were selected. Observations were conducted for a period of 6 months to determine the effectiveness of hospital waste management practices. The hospitals were grouped into 3 categories namely large, medium and small, and due cognizance of privately and publicly/government owned hospitals was made.

Table 6 Variables

List of Variables	Measure	Scale
Size of facility	Number of beds	Ordinal
Occupancy rate of hospital beds	Percentage Value	Ordinal
Frequency of incineration	Count Data	Ordinal
Medical waste segregation system	Percentage value	Ordinal
Type of services provided	Percentage value	Ordinal
Medical Waste Chain/Individual Perception	Percentage value	Ordinal
Medical Waste Chain by Facility	Percentage value	Ordinal
Comparison of Medical Waste Chain per Facility	Percentage value	Ordinal
Comparison of Medical Waste Chain (Regional versus District)	Percentage value	Ordinal
Comparison of Medical Waste Chain (District versus Special)	Percentage value	Ordinal
Comparison of Medical Waste Chain (Regional versus Special)	Percentage value	Ordinal
Operational Practices/Individual Perception	Percentage value	Ordinal
Operational Practices by Facility	Percentage value	Ordinal
Comparison of Operational Practices per Facility	Percentage value	Ordinal
Comparison of Operational Practices (Regional versus District)	Percentage value	Ordinal
Comparison of Operational Practices (District versus Special)	Percentage value	Ordinal
Comparison of Operational Practices (Regional versus Special)	Percentage value	Ordinal
Limitations within Facility	Percentage value	Ordinal
Comparison of Limitations (Regional versus District)	Percentage value	Ordinal
Comparison of Limitations (District versus Special)	Percentage value	Ordinal
Comparison of Limitations (Regional versus Special)	Percentage value	Ordinal
Comparison of Limitations (Regional versus Special)	Percentage value	Ordinal

The scaling of hospitals to large, medium and small was based on bed space, average bed occupancy rate, wards/units, staff strength and patients. Sampling was carried out for each category and vital information sought included nature of waste generation and disposal methods for both solid and liquid waste. Data were obtained by administering questionnaires to hospital staff such as consultants, medical officers, paramedics (matrons, nurses, cleaners, pharmacists), and administrative personnel.

The composition of the waste from each sampled hospital was estimated by sorting into five categories namely:

- I. Plastics, PVC and syringes
- II. Swabs, pads, gauze and absorbents
- III. Paper packages and bottles
- IV. Sharps/needles
- V. Kitchen/food wastes
- VI. Metal and glass

Trotter II (2012) mentioned that allocation of interview schedules in each of the ten study sites (after Turner *et al.* (2000) and Magnani (1997)) was based on three factors: (i) the estimated prevalence of the variable of interest – medical waste in this instance, (ii) the desired level of confidence and (iii) acceptance of margin of error. The sample size distribution of questionnaires was calculated according to equation (1).

$$n = t^2 \times \frac{p(1-p)}{m^2} \dots \dots \dots \text{Equation (1)}$$

where **n** = required sample size

t = confidence level at 95% (standard value of 1.96)

p = estimated prevalence of proper medical waste handling (10%)

m = margin of error at 5% (standard value of 0.05).

Then it followed that

$$n = t^2 \times \frac{p(1-p)}{m^2}$$

$$n = \frac{3.8416 \times 0.1(1-0.1)}{0.0025}$$

$$n = 138.29 \text{ (} \underline{n \approx 139 \text{ questionnaires)}} \text{)}$$

On weighted basis according to the number of beds determined for each facility then it followed that allocation could be as in Table 7.

Table 7 Allocation of interviews for participants

Name of facility	Number of beds	Percent (Weighted)	Rank of Facility	Total allocated per facility
Mofumahadi Mmanapo Mopeli Regional Hospital	270	27.81%	1	38
Dihlabeng Regional Hospital	150	15.45%	2	21
Medi-Clinic (Hoogland)	107	11.02%	3	15
Phekolong Hospital	100	10.30%	4	14
Thebe Hospital	100	10.30%	5	14
Nkhono Mantsopa Hospital	72	7.42%	6	10
Elizabeth Ross District Hospital	65	6.69%	7	9
Nketoana Hospital	45	4.63%	8	6
Phumelela Hospital	32	3.30%	9	6
Corona Sub-Acute Hospital	30	3.09%	10	6
Total	971	100%		139

Each sample size as given in Table 8 was applied to the sample sites for inclusion in the study as determined by a weighted base. The demarcation of the separate study sites was the facilities themselves. A coding (i.e. ranking) system was developed to provide identity for each of the facilities. Thereafter, a table of random digits was used to pick a random sample of units in each of the ten sites. All 139 responses through interviews were isolated for inclusion in the study.

3.10 Data collection and analysis

3.10.1 State of Operational Procedures

Collection of data in this regard was done by direct observation as to how waste was handled at each of the facilities visited (Appendix B). Other data on the current state of operational procedures with regard to the handling of medical waste was obtained from

official reports of the Provincial Department of Public Health, Bloemfontein, supplemented by Annual Health Reports of Districts and Local Municipalities in the study area. The information was presented in the form of a descriptive profile of medical waste management systems at each of the hospitals included in the study. The key features of this information were later carried forward into the results and discussion sections of the study.

Table 8 Distributions of interviews

Hospitals	RESPONDENTS						
	Head of Hospital	Heads of Department	Doctors and/or Surgeons	Pharmacist	Laboratory Supervisor	Medical Waste Handler	Total
Mofumahadi Mmanapo Mopeli Regional Hospital	2	8	16	4	4	4	38
Dihlabeng Regional Hospital	1	6	10	2	1	1	21
Medi-Clinic (Hoogland)	1	3	7	2	1	1	15
Phekolong Hospital	1	3	6	2	1	1	14
Thebe Hospital	1	3	6	2	1	1	14
Nkhono Mantsopa Hospital	1	4	2	1	1	1	10
Elizabeth Ross District Hospital	1	3	2	1	1	1	9
Nketoana Hospital	1	1	2	1	1	0	6
Phumelela Hospital	1	1	2	1	1	0	6
Corona Sub-Acute Hospital	1	1	1	1	1	0	6
Total							139

3.10.2 Elements of Medical Waste Chain

Data was collected by the use of interview together with direct observation in order to identify elements of medical waste chain in each of the facilities visited. The instruments used here were interview (Appendix A) and observation (Appendix B). In cases where

records were available, they were also looked at and useful information was extracted from those records to be used at a later stage. Analysis of the elements of the medical waste chain and relationships thereof, operational in the study area were observed at each of the hospitals to record and present a process map of the medical waste handling, collection and conveyance to the incinerator- where this existed. An observation schedule was filled capturing the characteristics of the frequency, volumes and movement of waste from generation to final destruction. Part of the information on the schedule was carried forward for use in objective (iii). The rest of the information was presented in the form of tables and descriptive statistics generated using Version 20 of the SPSS software package. Plots were generated for each set of variables to test for existence, or otherwise, of normal distribution. Outputs of these computations were reported in the results section of the study and some were carried forward into hypothesis testing.

3.10.3 Quantifying Standards for Handling Medical Waste

Quantification of current operations against standards for handling medical waste was done using data from observations. Descriptive statistics were carried computed by way of means, standard deviations and plots showing the extent of clustering and dispersal. Computer generated graphics were used to show differences in trends between performance and expected standards. Using the SPSS statistical package (Microsoft 2010), descriptive statistics generated and results were applied after specifying a confidence level of 95%. The results showed the nature, direction and strength of interactions between critical variables in the medical waste handling chain.

3.10.4 Critical technical and managerial limitations

Collection of data was accomplished by using the interviews coupled with direct observation on medical waste handling procedures in each of the facilities visited. The instruments used in this case were Appendix A and B. Descriptive statistics and computer generated graphics were employed to attach meaningful analysis to this information. Information obtained here would lead to identification of the critical technical and managerial limitations in the delivery of an efficient medical waste handling programme. Using results from objectives 1, 2 and 3, a set of limitations were extracted for further use in the discussion section of the dissertation. This was done to focus on the potential problems posed by disposal of hospital waste. The emphasis of the survey was placed on waste

generation in the hospital, disposal practices and disposal sites. To abide by ethics the names of the various medical facilities are not mentioned herein for confidentiality reasons. Data from various areas of the medical institutions were collected through direct field observations and interview survey. The medical waste management team, the Doctors and/or Surgeons, Administrative and support staff involved with the handling of the waste were interviewed about general medical waste management practices and their basic understanding of the waste management issue. Furthermore, the actual scenario was explained by the waste collectors of the hospital. The data on waste generation, disposal and storage, transportation and treatment facilities were collected from the hospital records with the help of the assigned authorities. The quantity of waste generated, where known, was also recorded by category.

The interview used in the study area was structured and the responses were recorded with the purpose of obtaining knowledge of the present scenario of waste generation and the management strategies followed in the hospital, and in order to identify the factors limiting proper disposal. Section A of Appendix A focused on general information of the medical facility setting, personal information of the participant to be interviewed and knowledge and/or possible link with medical waste management practice in the medical facility. Section B had more to do with awareness of waste management policy information on a national and local level. Section C focused on waste management practices in that particular medical facility in which the participant is working. In Section D, information about participant's waste management training was sort and Section E assessed the attitude of each individual participant with respect to waste management practices in that particular medical facility he/she is working in.

The interview addressed a wide array of medical waste management practices and could be summarized as follows: (i) Were there any defined procedures for collecting and handling of waste from specified units in the hospital? (ii) What happened between segregation and final disposal of particular types of waste such sharps, pathological waste, infectious waste, chemical waste, general waste? (iii) What types of containers or bags were used for the disposal? (iv) Where was the segregated waste stored while awaiting final disposal? (v) Does your hospital have a waste management plan and team to monitor medical waste management practices? (vi) Who handled the segregated waste, what was

the designation of the person responsible for organizing and managing the waste collection, handling, storage and disposal? (vii) Were the waste handlers using proper protective clothing during handling and also have they been given proper instructions or training? (viii) Were you aware of any legislation related to medical waste management which has been formulated by the government?

3.11 Ethical Considerations

The South African Medical Research Council (MRC) promotes the four principles of biomedical ethics:

- I. Principles of Autonomy (respect for the person - a notion of human dignity)
- II. Principles of Beneficence (benefit to the research participant)
- III. Principles of Non-maleficence (absence of harm to the research participant)
- IV. Principles of Justice (notably distributive justice - equal distribution of risks and benefits between communities)

The principle of autonomy: participants that are capable of deliberation about personal choices should be treated with respect for their capacity of self-determination and be afforded the opportunity to make informed decisions with regard to their participation in research. Therefore, there must be special protections for those with diminished or impaired autonomy i.e. dependent and/or vulnerable participants need to be afforded safeguards against harm or abuse.

The principle of confidentiality: a participant's right to both privacy and confidentiality must be protected. The researcher must ensure that where personal information about research participants or a community is collected, stored, used or destroyed, this is done in ways that respect the privacy or confidentiality of participants or the community and any agreements made with the participants or the community.

The principle of justice: justice imposes an ethical obligation to treat each person in accordance with what is right and proper. In research this is primarily distributive justice whereby there should be equitable distribution of both burdens and benefits of research participation. It is an ethical imperative that the study should leave the participant and/or community better off or no worse off. Researchers have an obligation to justify their choice

of research questions and to ensure that such questions are neither gratuitous nor result in the exploitation of study participants. The selection, recruitment, exclusion and inclusion of research participants must be just and fair, based on sound scientific and ethical principles. No persons may be inappropriately or unjustly excluded on the basis of race, age, sex, sexual orientation, disability, education, religious beliefs, pregnancy, marital status, ethnic or social origin, conscience, belief or language. Where research involves participants from vulnerable communities, added protection will be necessary to safeguard their vulnerabilities. There needs to be justification for doing research in vulnerable communities. Moreover, the research should be responsive to their particular vulnerabilities. Enhanced or added consent procedures would be necessary where appropriate. Vulnerable communities should not be targeted for research just because of administrative and logistical ease of availability.

The fourth principle did not arise in this kind of research. The consent to participate in the study was sought and participants were informed that participation was voluntary. However, participants were encouraged to participate in the study. The safety, rights and dignity of the participants was of primary concern and all information gained from them was strictly confidential. Responses from respondents were strictly for research purposes, the identity of respondents and their personal details was confidential, participants were free to withdraw at any time, the rights of participants were explained to them and that the proposal was presented to the North West University F.A.S.T. Ethics Committee and the results of evaluation indicate that a formal Ethics Form was duly filled in. The accompanying permission documentation was attached and clearance given.

Ethical considerations are essential to any form of data collection in a humanitarian operation. Collecting information for any purpose, including monitoring, assessments or surveys, could put people at risk not only because of the sensitive nature of the information collected, but also because simply participating in the process could have caused people to be targeted. The risks could range from physical violence to social marginalization and were often unknown to the individual soliciting the information. Therefore, participants were treated fairly and with dignity. Because the research involved an intrusion into the private lives of the participants, the researcher was always respectful, polite and reliable to the respondents. This helped to build rapport between the interviewer and respondents.

Usually proper or prior training of field personnel represented a critical aspect of quality control (see Patwary *et al.* 2012). The researcher adhered to the use of standardized protocols that ensured safe and ethical collection of data, and ensured compatibility among different groups. A proper procedure to manage the selected informants was followed at all times. In addition, previous experience of the researcher was valuable concerning possible problems that could be faced and how to tackle the issues.

The researcher signed a statement that he would not reveal identifying information to anyone outside the research. Furthermore, code names were used in all field notes. In some cases, interviews took place in a quiet confidential area in a mutually convenient location particularly for the identifiable and freely moving personnel of the visited medical facility. Possible precautions were taken to minimize the risks during the survey. Personnel protective equipment (PPE) was used as appropriate (gloves, mask, safety glasses, disinfectant soap and cream, safety shoes, safety hat, first aid kit). The use of PPE was rigorously observed and enforced. All of the participants were shown a letter of reference from the North-West University (Appendix C). This and the researcher's student card were used as a proof of identity.

3.12 Summary

This chapter has addressed the design of the research which centred on field surveys and measurement followed by administration of interviews supplemented by secondary data from official sources at provincial and national levels. It indicated how the choices of instruments were done and for what purpose. The chapter has also outlined how the medical facilities were chosen in the study area; specification of variables determined, identified and stated the unit of analysis used in the research. Sampling procedures were identified including the target groups. The chapter also mentioned how data for specific research objectives was collected, prepared and finally analyzed. In addition, ethical issues that have to be considered while conducting research were specified. The next chapter presents results and analysis.

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Introduction

The presentation of results is done at three levels. The first level addresses the individual basis of responses obtained from the respondents and the second level addresses the responses obtained at the level of the health facility and the last level addresses results obtained at the collective levels of health settings. It was very necessary to have this in order to inter-compare how the different facilities handle waste management. The analysis was seeking to bring about any differences that could arise as result of the facility size, operational procedures or the kind of services offered there since all the facilities visited are not of the same size.

4.2 Status of Current Medical Waste Management Practices

The results presented here show the operational procedures in the medical facilities as to how medical waste is handled. The number of respondents from regional hospitals was 38, representing 27.5% of the total respondents, from the district hospitals it was 68 (respondents representing 49.3% of the total respondents) and there was 32 respondents from other hospitals (representing 23.2% of the total respondents) (Figure 7). The composition of respondents by gender was 61% females while males made 39%.

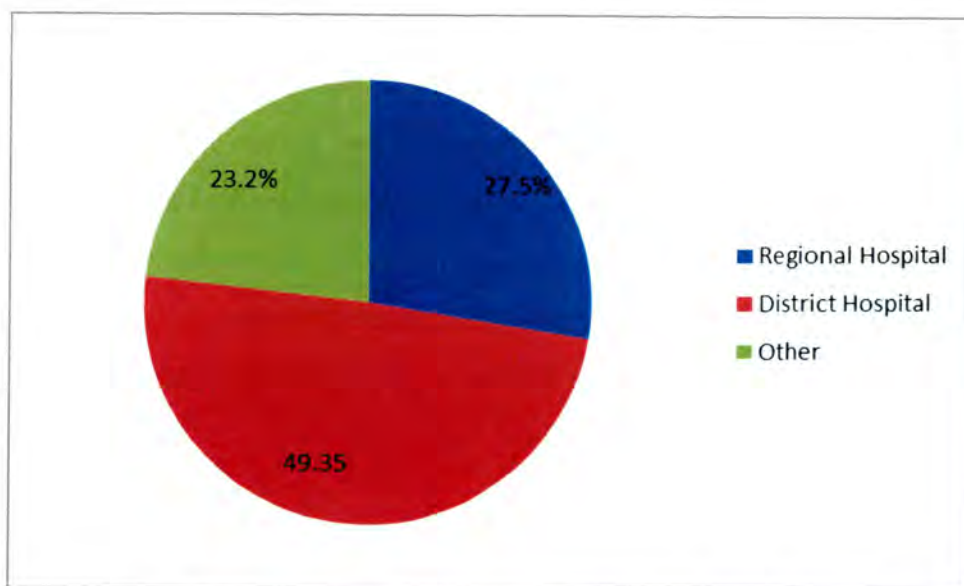


Figure 7 Respondents per Level of Medical Facility

On the awareness of any legislation relating to hospital waste management, 77.5% of the respondents (i.e. 107 respondents) reported that they were not aware of any legislation relating to hospital waste management while 22.5% (i.e. 31 respondents) indicated that they were aware of such legislation. Of these respondents who were at least aware of the legislation governing hospital waste management, 15.9% of them (i.e. 22 respondents) correctly mentioned that the legislation is NEMA, 6.5% (i.e. 9 respondents) could not say which piece of legislation they were referring to and 77.5% (i.e. 107 respondents) did not comment. When respondents were asked about the availability of a waste management plan in their medical facilities, the responses were such that 71% (i.e. 98 respondents) indicated that there was no such while 29% (i.e. 40 respondents) indicated that there was a waste management plan in place at their medical facility. All respondents indicated that nothing existed with respect to responsibilities attached to their job descriptions and that there was no authorization required in handling medical waste.

When respondents were asked about whether waste should be segregated, the responses were 79% in disagreement (i.e. 109 respondents) and 21% (i.e. 29 respondents) agreed. The results obtained for waste disposal method showed that incineration was done by 47.8% of the respondents (i.e. 66 respondents), containment was done by 30.4% (i.e. 42 respondents) and segregation was done by 21% (i.e. 30 respondents). Figure 8 shows results that 79% of the respondents (i.e. 109 respondents) indicated that they did not know who did the segregation while 13.8% of the respondents (i.e. 19 respondents) indicated that it was done by supervisors, 5.8% (i.e. 8 respondents) indicated that it was done by medical waste handler and 1.4% (2 respondents) pointed towards the Doctor and/or Surgeon.

With respect to colour-coding waste for disposal, 89.9% of the respondents (i.e. 124 respondents) were in the affirmative while 10.1% (i.e. 14 of the respondents) were not. The colour-coding was appropriately matched by those who did it such that the scores for matching red was 5.1% indicating 7 respondents; yellow was 4.3% indicating 6 respondents, black was 2.9% indicating 4 respondents while 87.7% did not (Figure 9).

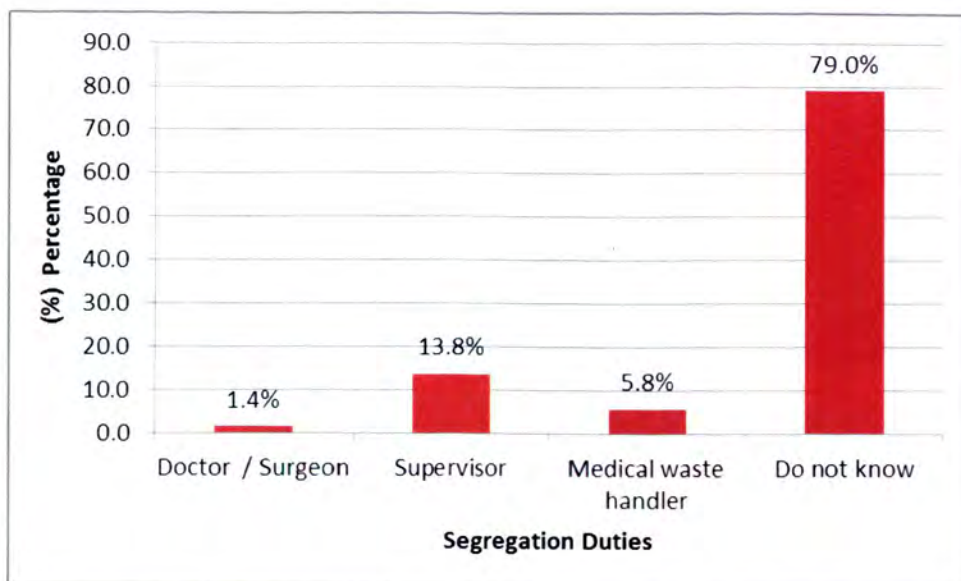


Figure 8 Segregation Duties per Level of Medical Facility

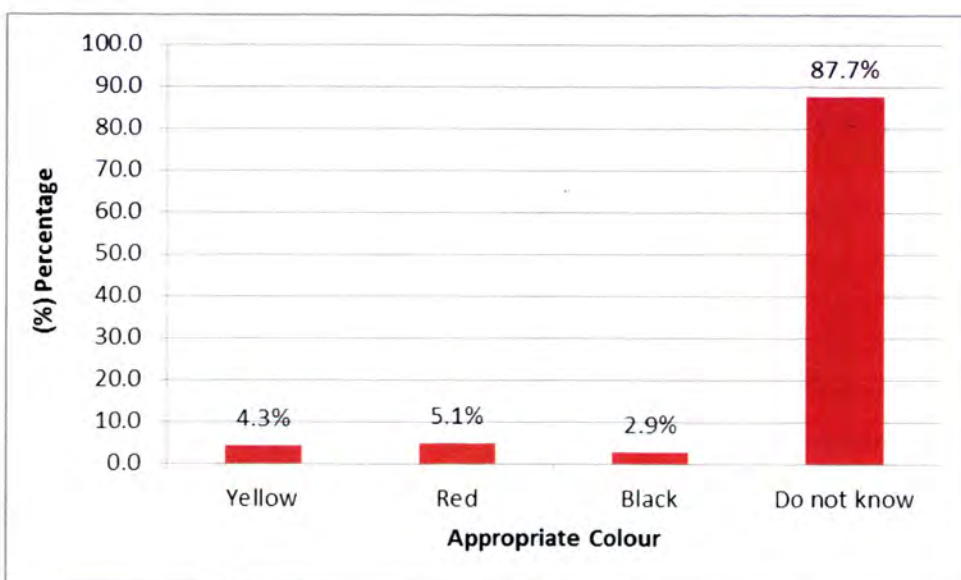


Figure 9 Appropriate Colour-coding Levels of Respondents

Disposal of medical waste (Figure 10) was in the order 89.1% (i.e. 123 respondents), 5.8% (i.e. 8 respondents) and 5.1% (i.e. 7 respondents) for each department collects, dumping into municipal bin and use of any other authorized waste collector respectively. No register for waste was confirmed by 97.8% (i.e. 135 respondents) while 2.2% (i.e. 3 respondents) affirmed the presence of a waste register at their medical facility.

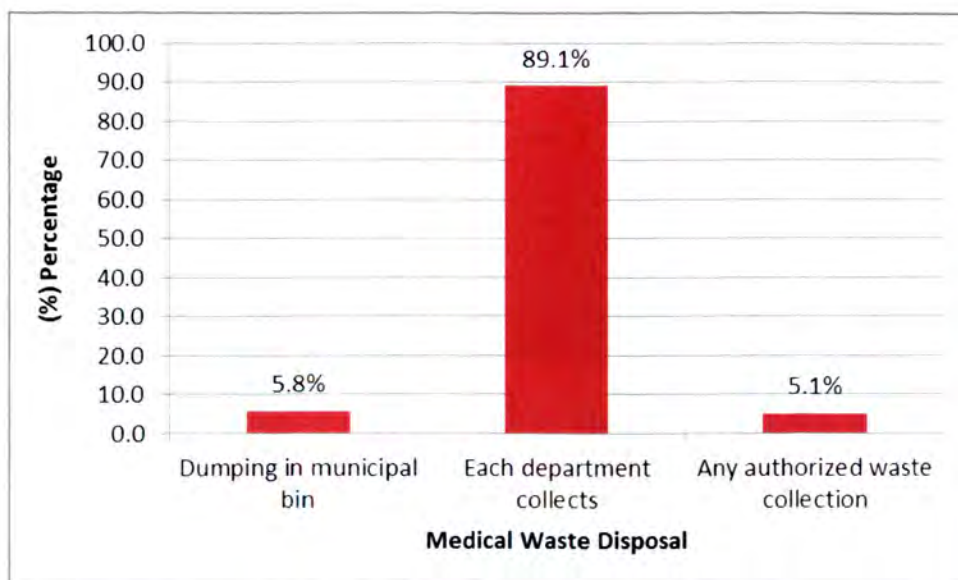


Figure 10 Respondents' Method of Medical Waste Disposal

The results showed 100% non-existence of an audit in the last three years being carried. Regarding respondents having undergone training on medical waste management and providing annual education on waste management to employees in any of the medical facilities visited, 78.3% of the respondents (i.e. 108 respondents) were eager to attend any training programme relating to medical waste management while 21.7% (i.e. 30 respondents) were not eager.

At the facility level, Figure 11 shows that for the respondents who colour-coded waste for disposal, segregation was done by 26.7% of the respondents (i.e. 8 respondents) while 73.3% (i.e. 22 respondents) did not, containment was done by 9.5% of the respondents (i.e. 4 respondents) while 90.5% (i.e. 38 respondents) did not. Incineration was done by 3.0% of the respondents (i.e. 2 respondents) while 97.0% of the respondents (i.e. 64 respondents) did not. Those respondents who practiced incineration, 50.0% (i.e. 1 respondent) could match waste relevant to yellow. Of the respondents who segregated medical waste, 38.5% (i.e. 5 respondents) could match waste relevant to yellow. None of the respondents who practiced containment could match waste relevant to yellow. Red was matched by all those who practiced containment (i.e. 2 respondents), 50.0% by those who incinerated (i.e. 1 respondent) and 30.8% by those who segregated. Only 30.8% (i.e. 4 respondents) of those who segregated correctly matched black.

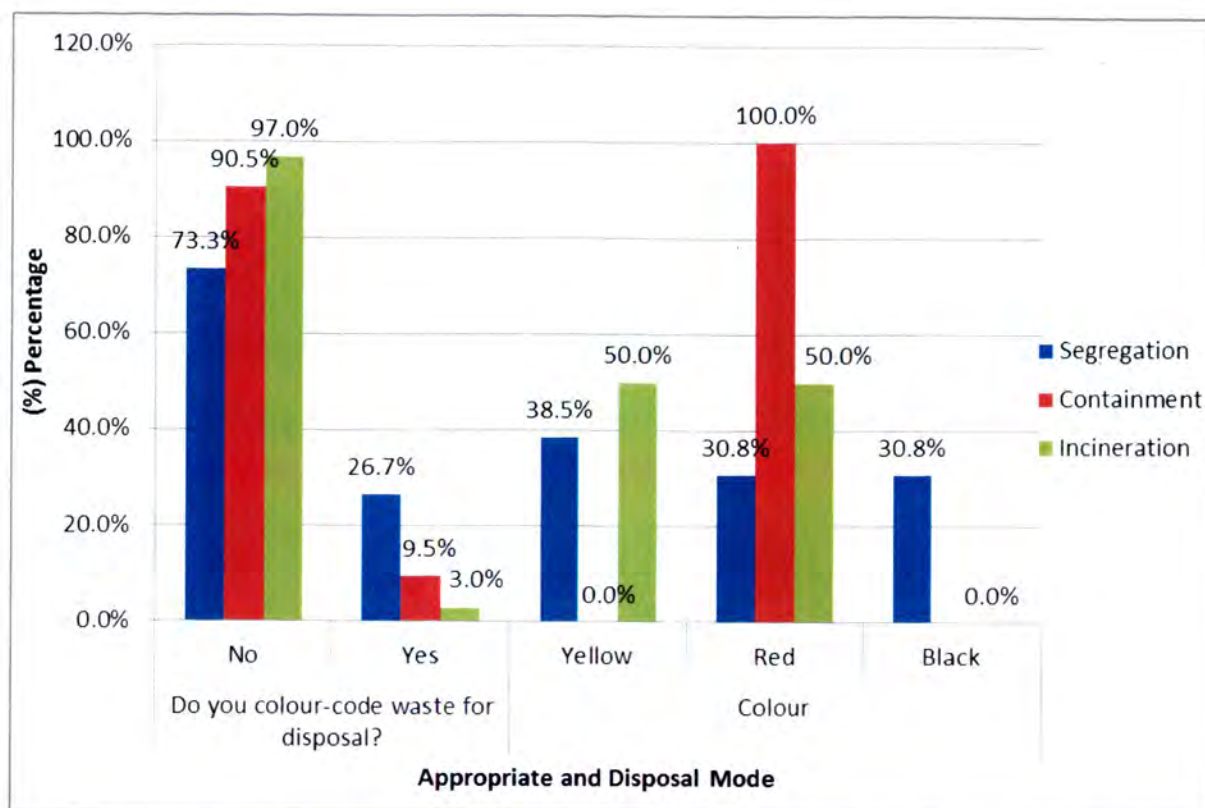


Figure 11 Appropriate Colour-coding and Disposal Mode per Facility

Figure 12 shows that of the respondents who labeled with the bio-hazard symbol waste for disposal, 9.5% favoured containment, 6.7% favoured segregation and 6.1% incinerated while respondents who did not label infectious waste with the bio-hazard symbol for each of the disposal methods were in excess of 90% of the respondents. Of those who maintained the presence of a waste register, 10% of the respondents segregated waste for disposal. All respondents confirmed no existence of audits in the last three years. As shown in Figure 13, of those who dumped into municipal bin 10% of the respondents also segregated waste for disposal, 9.5% practiced containment and 1.5% incinerated. Nearly 90% of the respondents indicated that each department is responsible for collecting its waste irrespective of the final disposal method. The results further showed that incineration was favoured by 7.6% of the respondents, who also felt waste could be collected by any other authorized waste collector; containment was favoured by 4.8% of the respondents and segregation by none.

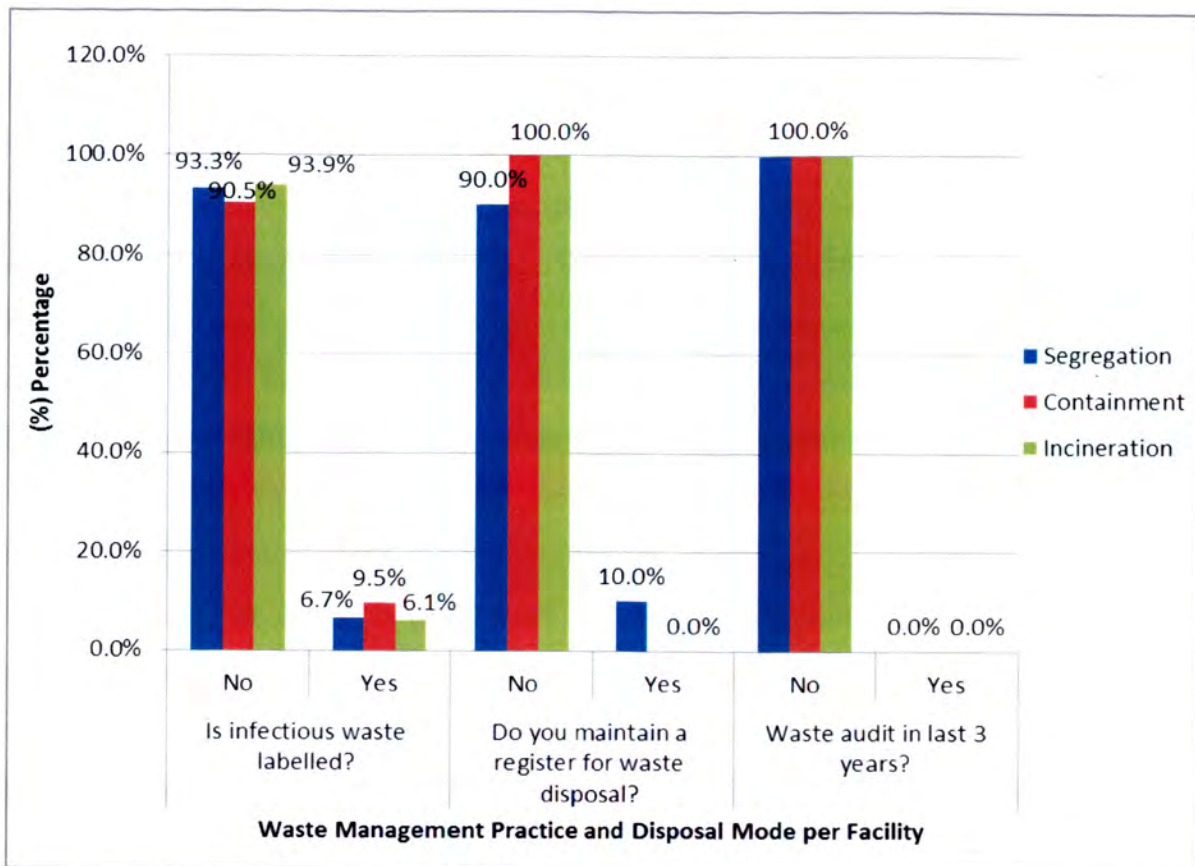


Figure 12 Waste Management Practice and Disposal Mode per Facility

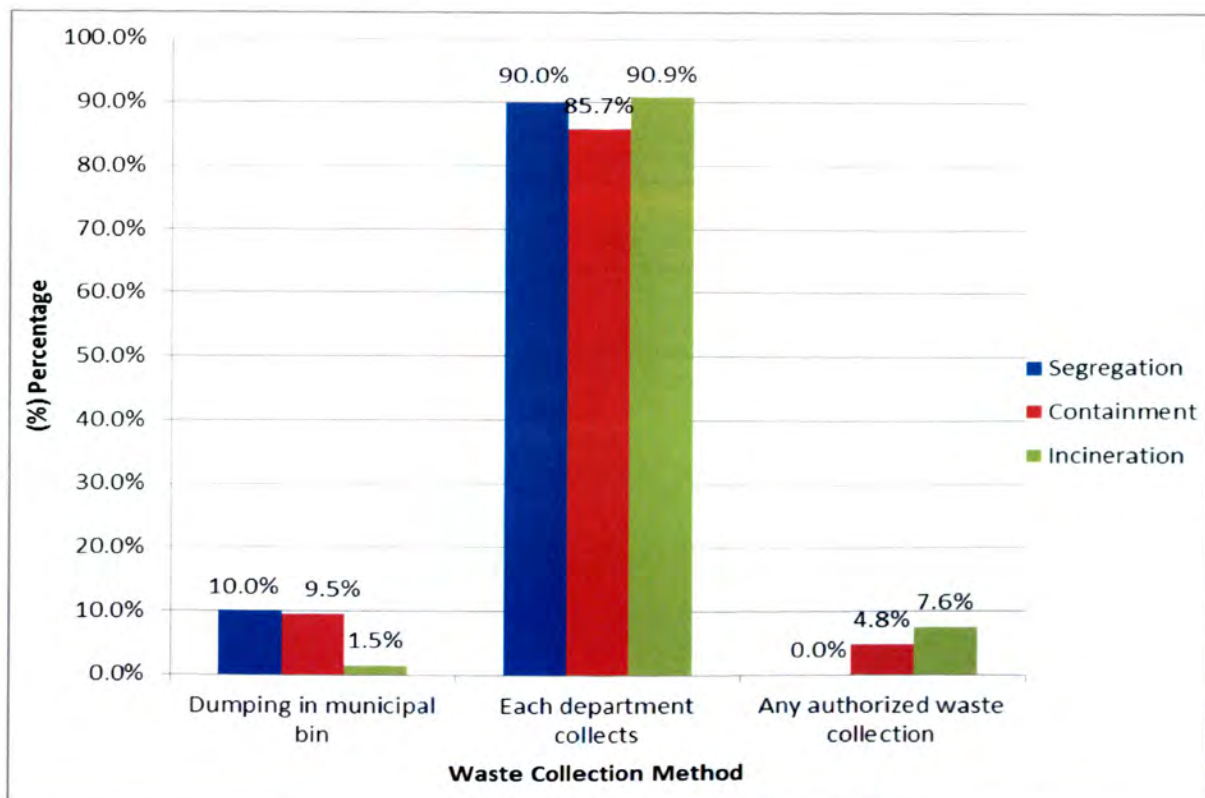


Figure 13 Waste Collection and Disposal Mode per Facility

At the level of health settings, the results shown in Figure 14 indicate that at regional hospitals 21.1% of the respondents (i.e. 8 respondents) were aware of waste management legislation while 78.9% (i.e. 30 respondents) were not aware. At the district and other specialized hospitals the values stood at 20.6% of the respondents (i.e. 14 respondents) and 28.1% (i.e. 9 respondents) for those who were aware and 79.4% (i.e. 54 respondents) and 71.9% (i.e. 23 respondents) for those who not aware, respectively. The presence of a waste management plan was confirmed by 36.8% of the respondents (i.e. 14 respondents) at regional hospitals, 20.6% (i.e. 14 respondents) at district and 37.5% (i.e. 12 respondents) at other specialized hospitals. On the other hand, 63.2% of the respondents (i.e. 24 respondents) could not confirm the presence of a waste management plan in their regional medical facility. At district hospital level, 79.4% of the respondents (i.e. 54 respondents) could not confirm the presence of waste management plans and at specialized hospital level the presence was not confirmed by 62.5% of the respondents (i.e. 20 respondents). In all health settings it was found that no authorization and attachment of waste management was done to any job description (Table 9).

Table 9 Health Settings and Waste Management Policy

Health setting	Awareness of MW legislation		Presence of MW management plan		Waste management responsibilities		Awareness of authorisation	
	No	Yes	No	Yes	No	Yes	No	Yes
Regional Hospital	30 78.9%	8 21.1%	24 63.2%	14 36.8%	38 100.0%	0 0.0%	38 100.0%	0 0.0%
District Hospital	54 79.4%	14 20.6%	54 79.4%	14 20.6%	68 100.0%	0 0.0%	68 100.0%	0 0.0%
Other	23 71.9%	9 28.1%	20 62.5%	12 37.5%	32 100.0%	0 0.0%	32 100.0%	0 0.0%

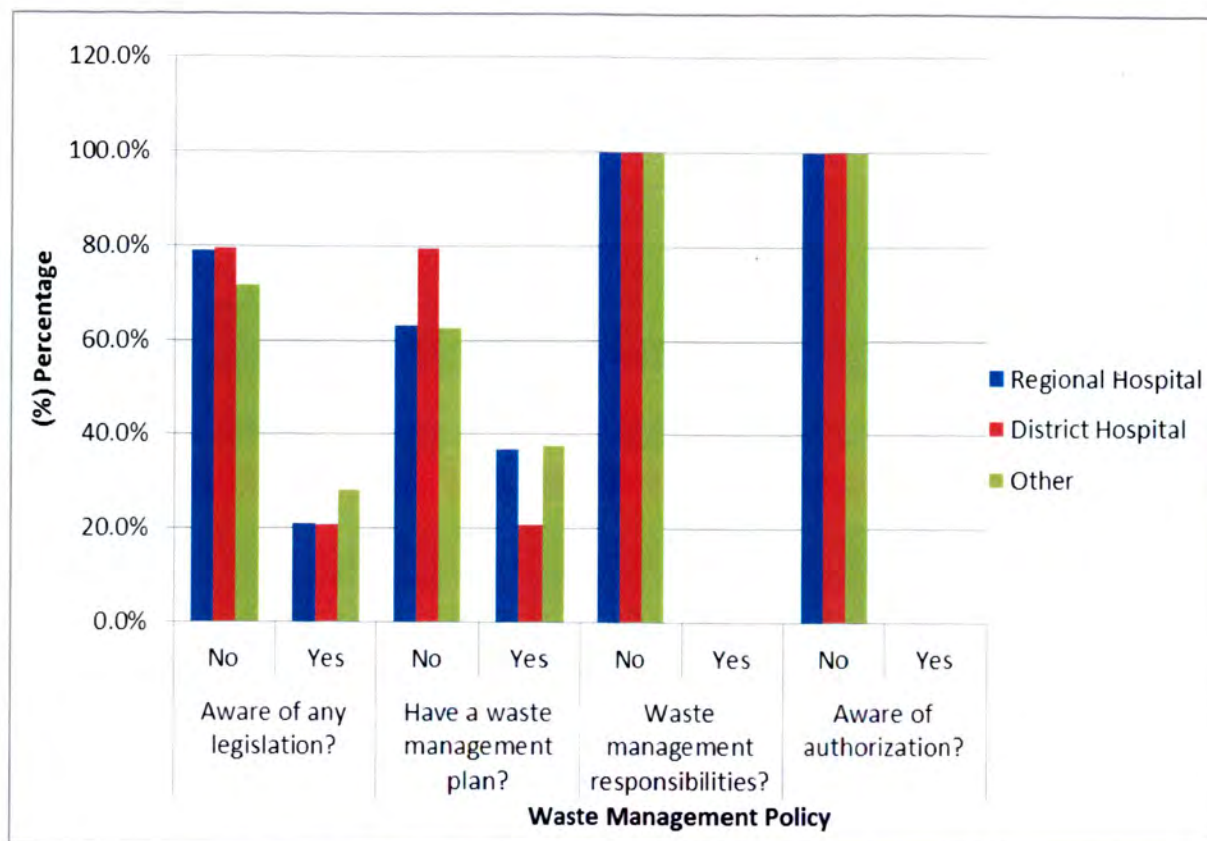


Figure 14 Health Settings and Waste Management Policy

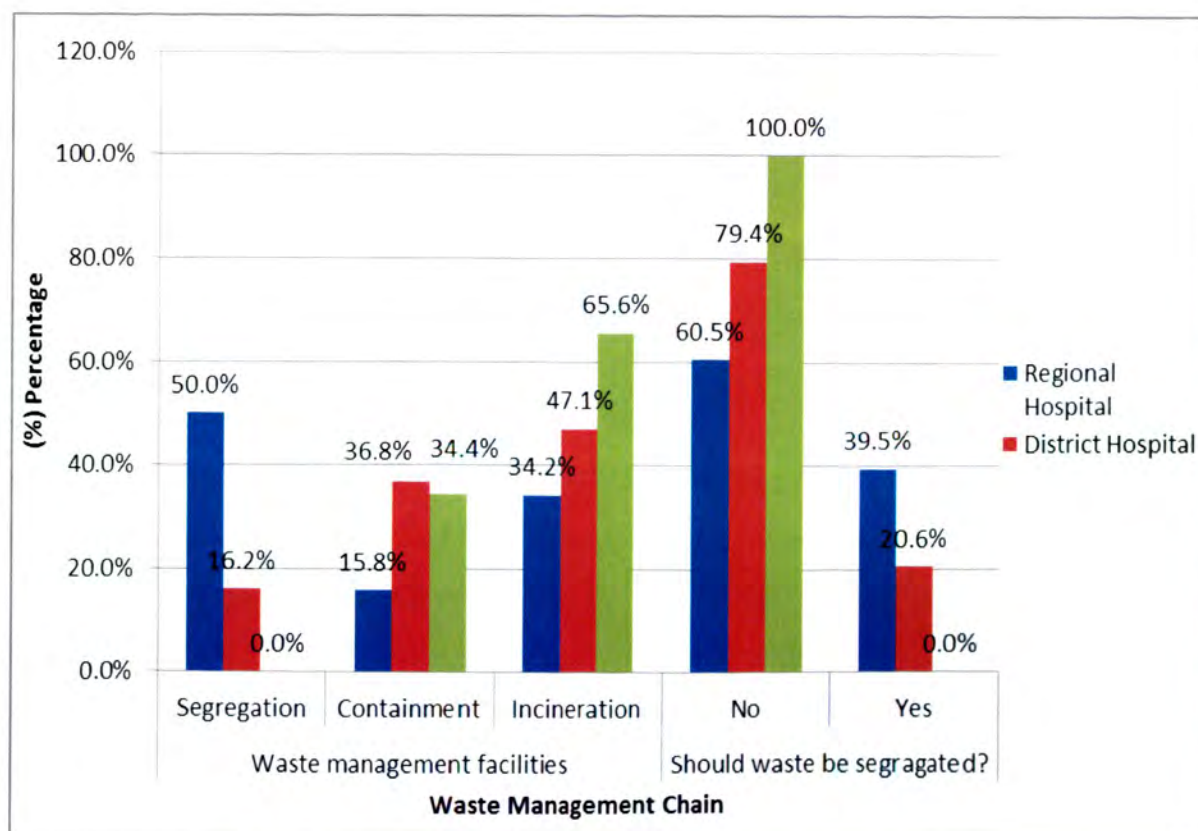


Figure 15 Health settings and Waste Management Chain

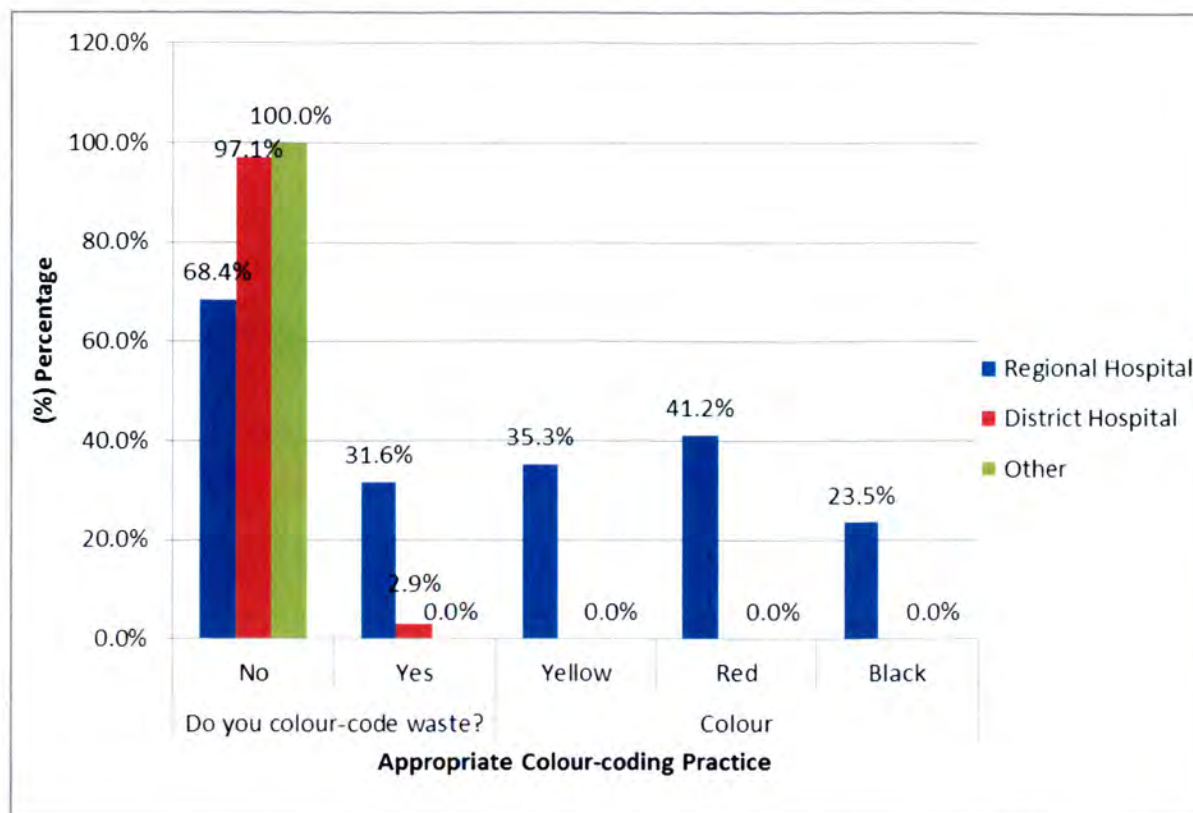


Figure 16 Health settings and Colour – coding Practice

The results shown in this section show that there are similar shortcomings noted in other studies elsewhere (Aghapour *et al.* 2013, Alavi *et al.* 2013). They also reveal the seriousness with which current operations have to be viewed (Kinnarinen *et al.* 2013) and that the problem is not unique for the study area alone. The first objective of this study was to describe the current state operational procedures at a selection of medical facilities. On the basis of these results, this has been addressed.

4.3 Analysis of Medical Waste Management Chain

Direct observation using an observation schedule (Appendix B) done while visiting the individual health settings showed that hazardous waste was not segregated from MGW at the source of generation. Observations by researcher showed several inappropriate procedures. Both types of waste were collected in common municipal bins. The sharps' containers were in some instances more than 75% full with sharps. Observations also revealed the inappropriate use of municipal bins to collect sharps. Extraordinarily sharps' containers (i.e. beez bins) were more than 75% filled, trails of blood could be seen on some

facilities' floors, blood soaked swabs were found in municipal bins and medical waste was collected and casually carried by hand amidst patients and visitors and not on wheeled trolleys. It is the researcher's view that some material objects were lacking due to stocking since when extended questions were posed to some respondents it was often found that no proper protective gear was regularly supplied, no proper containers (i.e. beez bins), and / or colour – coded plastics and / or appropriate bio – hazard symbols.

At one of the regional facilities, waste is dumped together irrespective of the nature of the waste (Photograph 1) which shows intermingled waste as a follow-up scenario from within the medical facility. The inappropriate use of plastics to contain infectious waste is shown in Photograph 2. Sometimes temporary storage facilities were observed to be overfilled and waste was just left outside the storage facility (Photograph 3). This particular storage facility was not locked even where the sharps' containers were temporarily stored (Photograph 4). On the very same facility, a scavenger was found in this unlocked and over-filled central temporary storage busy going through the waste and several sharps containers were not even sealed. This sighting was not unique to this facility alone. No clear indication of when the off-site transport would clear the storage was given, indicating a possibility of medical waste over-staying at the central temporary storage.



Photograph 1 Intermingled Medical Waste (Source: Author 2012)



Photograph 2 Inappropriate Uses of Plastic Containers (Source: Author 2012)



Photograph 3 An Overfilled Temporary Medical Waste Storage Facility (Source: Author 2012)



Photograph 4 An Unlocked Temporary Medical Waste Storage Facility showing Sharps' Containers (Source: Author 2012)

In regional hospitals, generally the flow diagram for medical waste can be such that little or no segregation was done at the source, waste was collected towards a central storage facility to await off-site transportation by a privately sourced company for this purpose. In some instances medical waste was incinerated on-site at a nearby incineration plant. At district hospitals, most waste was actually incinerated on-site at an incineration plant. Deep burial was observed to be a favourable option for special and other smaller medical facilities.

The flow diagram of medical waste observed at the regional level hospitals is as shown in Figure 17.

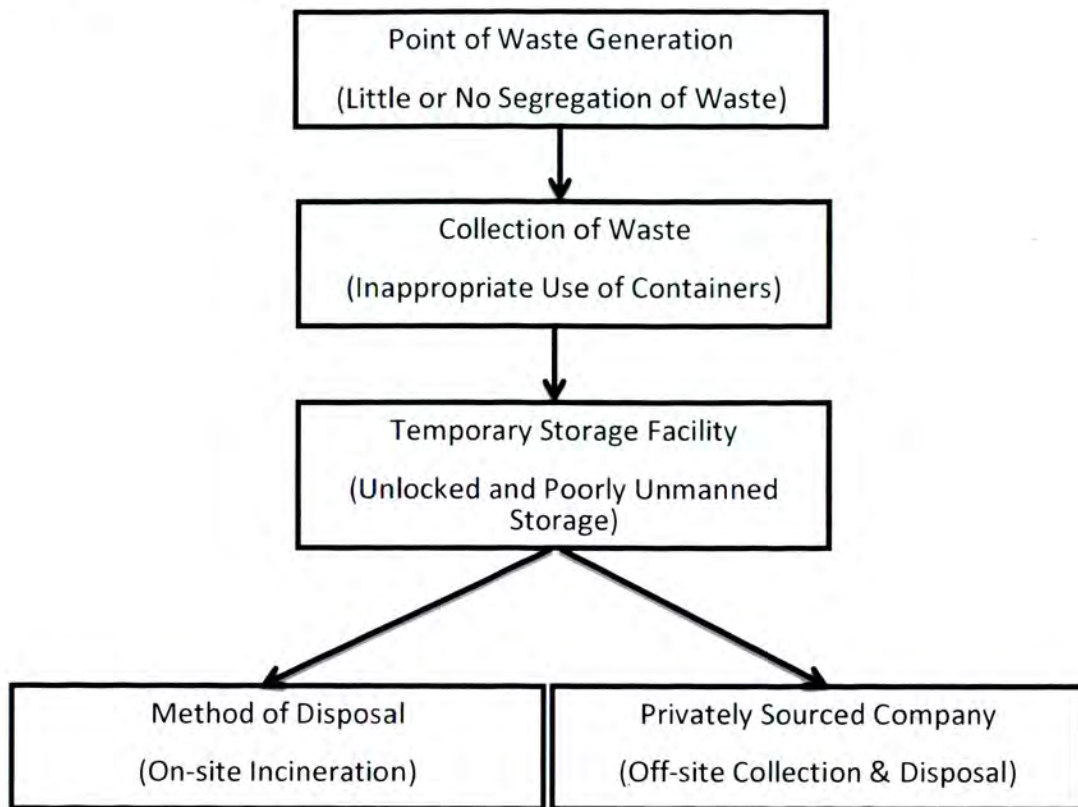


Figure 17 Medical Waste at the Regional Level Hospitals

The flow diagram of medical waste observed at the district level hospitals is as shown in Figure 18.

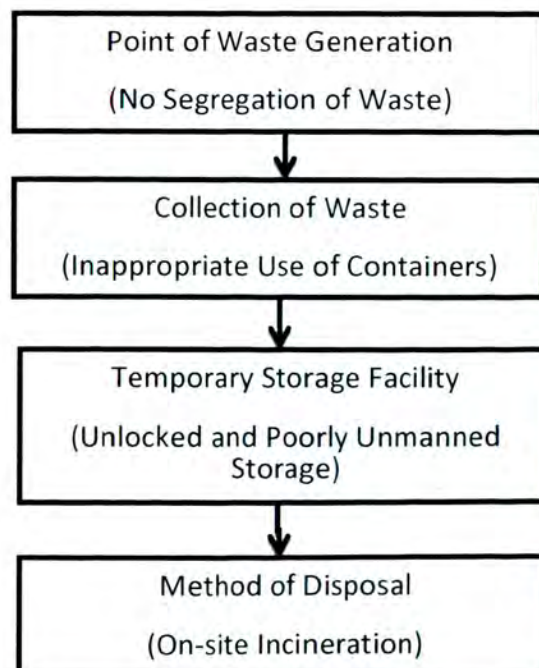


Figure 18 Medical Waste at the District Level Hospitals

It is noted that Figures 17, 18 and 19 show variations in the medical waste chain. These variations are related to the category of the medical facility which translates into differences in physical size, personnel compliment, support infrastructure, position in the medical hierarchy and size of budget. These differences may in the end impact on the levels of efficiency in the management of medical waste.

The flow diagram of medical waste observed at specialised and other hospitals is as shown in Figure 19.

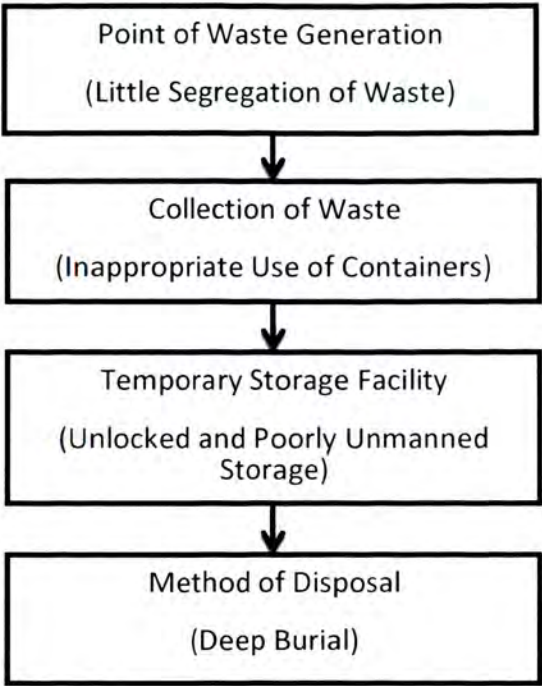


Figure 19 Medical Waste at Specialised and Other Hospitals

This section has presented the results and discussion thereof, of the medical waste chain at medical facilities in the study area. It has been noted that the physical characteristics of the waste chain varies with the class of the medical facility. The largest of these facilities appear to conform to national guidelines on the handling and transfer of medical waste up to final disposal. On the basis of these results, research objective II which required an analysis of the medical waste chain has been addressed.

4.4 Operating Standards

Results from the conduct of a t-test on the three health settings, using “Central” as the control appear in Table 10. The last column shows the mean per volume of waste per patient per day. The ranking of the health facilities in terms of the number of beds is in the

order of: (i) regional, (ii) district, (iii) central, and (iv) special. A comparison of the results shows that the size of the facility does not appear to be related to the mean volume of medical waste generated. Regional scores a value of 0.55, district scores 0.79, special scores 0.08 while the control scores, the highest at 1.42.

Table 10 Statistics - Average Rates

Hospital	n	Mean	Mean Difference	Standard rate
Regional	30	1.337	0.787	0.55
District	60	1.468	0.678	0.79
Central	45	1.465	0.045	1.42
Special	15	1.715	1.635	0.08

In Table 11, average rates are compared to standardised rates and in Table 12, confidence intervals are presented. . The t-statistic and the p-value are shown for each category of medical facility. The p-value shows the significance of the statistical relationship between volume of waste generated and the number of hospital beds. The rule for rejection of the null hypothesis states that: *Reject H_0 if $p > 0.05$* . The p-value scores in Table 11 indicates that all fall below the cut off ceiling of 0.05. It follows therefore that there is no statistically significant relationship between the volume of medical waste generated and the number of hospital beds. The null hypothesis is therefore accepted.

Table 11 One sample T-Test: Average Rates compared to Standardised Rates

Hospital	t-statistic	p-value
Regional	11.677	0.000
District	52.351	0.000
Central	3.627	0.001
Special	50.461	0.000

The p-value is 0.000 which is less than 0.05 and this means that the amount of waste generated at specialised hospitals is different from the standards value of 0.08. It is actually higher than the standard rate, the difference is 1.635.

Table 12 Confidence Interval of the Difference

Hospital	95%	
	Lower	Upper
Regional	0.649	0.925
District	0.652	0.704
Central	0.020	0.070
Special	1.565	1.704

This section has presented results and discussion centred on comparing the differences in the performance of the various facilities in this study. Analysis has shown differences between the facilities in terms of the amount of waste generated and the size of the facility. It has been shown, as expected, that the larger facilities generate more waste, requiring higher cost overheads. In this regard, objective III which called for a comparison of performance differences across the facilities in the study area has been achieved.

4.5 Limitations in Waste Management Handling

The obvious limitation towards effective waste management is identified as lack of training. The training lacked from the point of view of waste generation and composition of waste, physical, thermal and biological treatment methods, environmental management practices, collection and transport of medical waste, composting and digestion of medical waste, recycling, reducing, reusing, landfilling and aftercare of hazardous waste. Of the 138 respondents interviewed 12.3% of the respondents were heads of departments, 11.6% were supervisors and 76.1% were pharmacists. The education level shown in Figure 20 varied widely and showed no relationship to waste management practices (i.e. Senior Secondary = 54.3% of the respondents, Junior Secondary = 26.1% of the respondents, Graduate = 4.3% of the respondents, Post-Graduate = 2.2% of the respondents and Illiterate = 13.0% of the

respondents). The levels of respondents for lack of awareness of legislation pertaining to medical waste and lack of waste management plans at their hospitals were high. All respondents were also not aware of any authorisation requirements relating to waste management handling.

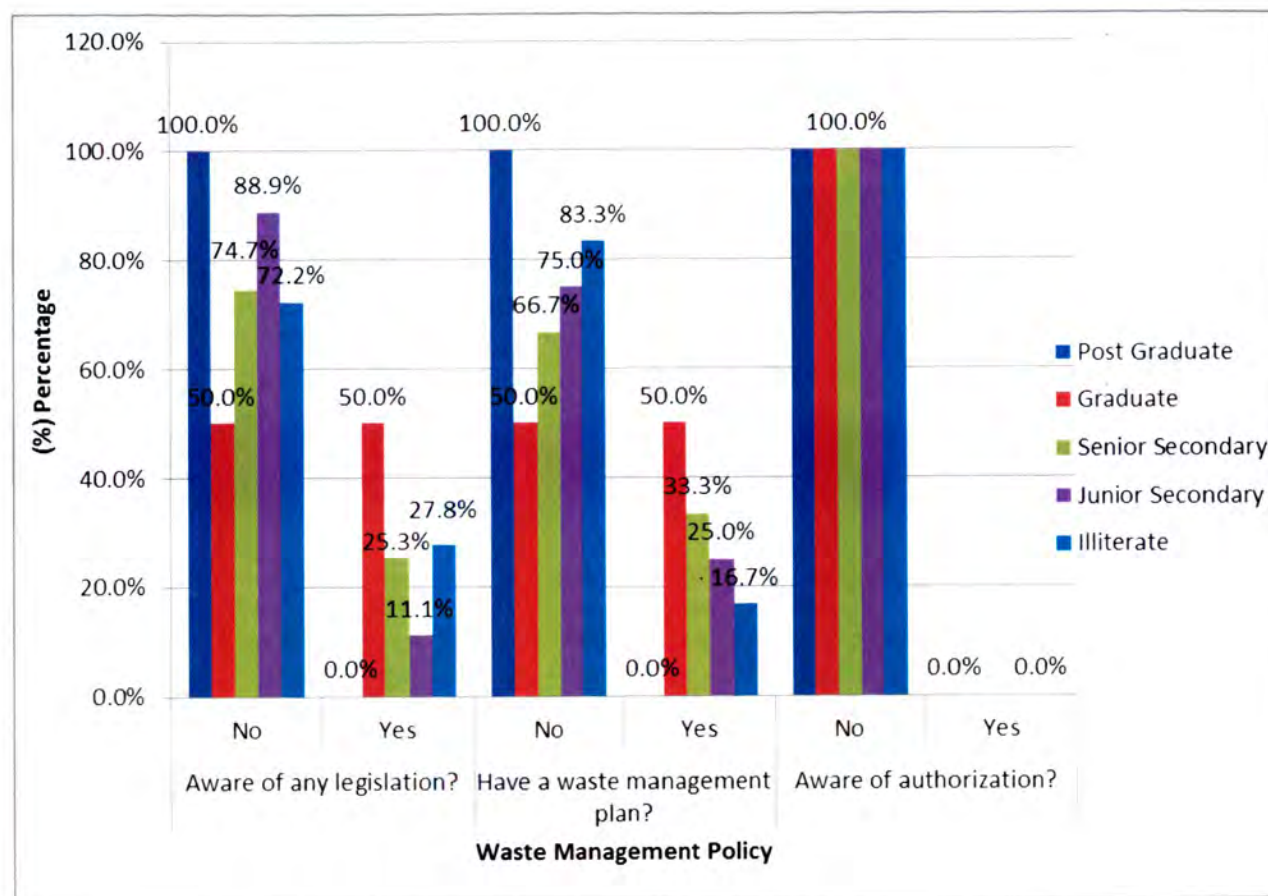


Figure 20 Levels of Education and Waste Management Policy

Results on attitude assessment are given in Figure 21. Safe management of medical waste was observed not to be an issue by 75.4% of the respondents, 18.1% of the respondents agreed to the fact that it should be an issue and 6.5% bore no comment. 76.8% of the respondents saw safe waste management as the responsibility of government, 16.7% of the respondents did not agree and 6.5% did not offer any comment. Respondents who favoured team work or those who indicated that no class of people should be responsible for safe waste management were supported by 81.2%, 14.5% of the respondents disagreed and 4.3% did not comment. Agreement with the statement that safe management efforts

by the hospital increased financial burden on management was at 75.4% of the respondents, 18.1% of the respondents disagreed and 6.5% did not comment. Safe waste management was also perceived as an extra burden on work by all respondents.

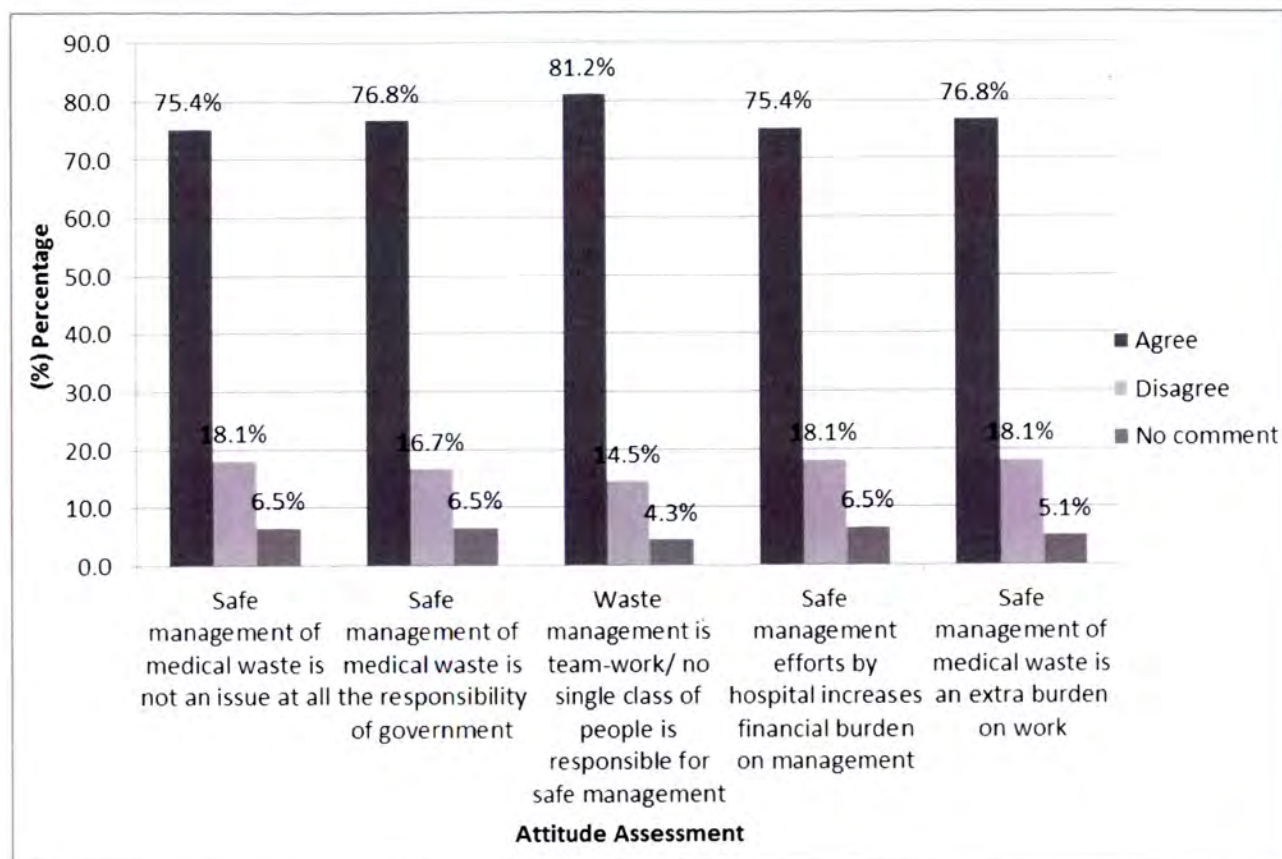


Figure 21 Individual Attitude Assessments towards Waste Management

With regard to health facilities as shown in Figure 22, attitude levels differed in that safe waste management was observed not as an issue, for 44.7% of the respondents at regional, 80.9% of the respondents at district and 100% of the respondents at specialised hospital settings. This kind of response was also observed when respondents were asked if safe waste management was the responsibility of government, regional was 60.5% of the respondents, district at 75.0% of the respondents and specialised hospitals at 100% of the respondents in agreement. Responses showed a more or less similar pattern for whether safe waste management put an extra financial burden on management and whether it put an extra burden on work. The responses were 31.6% of the respondents, 88.2% of the

respondents and 100% of the respondents for regional, district and specialized hospitals, respectively, for the former question and 55.3% of the respondents, 77.9% of the respondents and 100% of the respondents for the latter one (Figure 23).

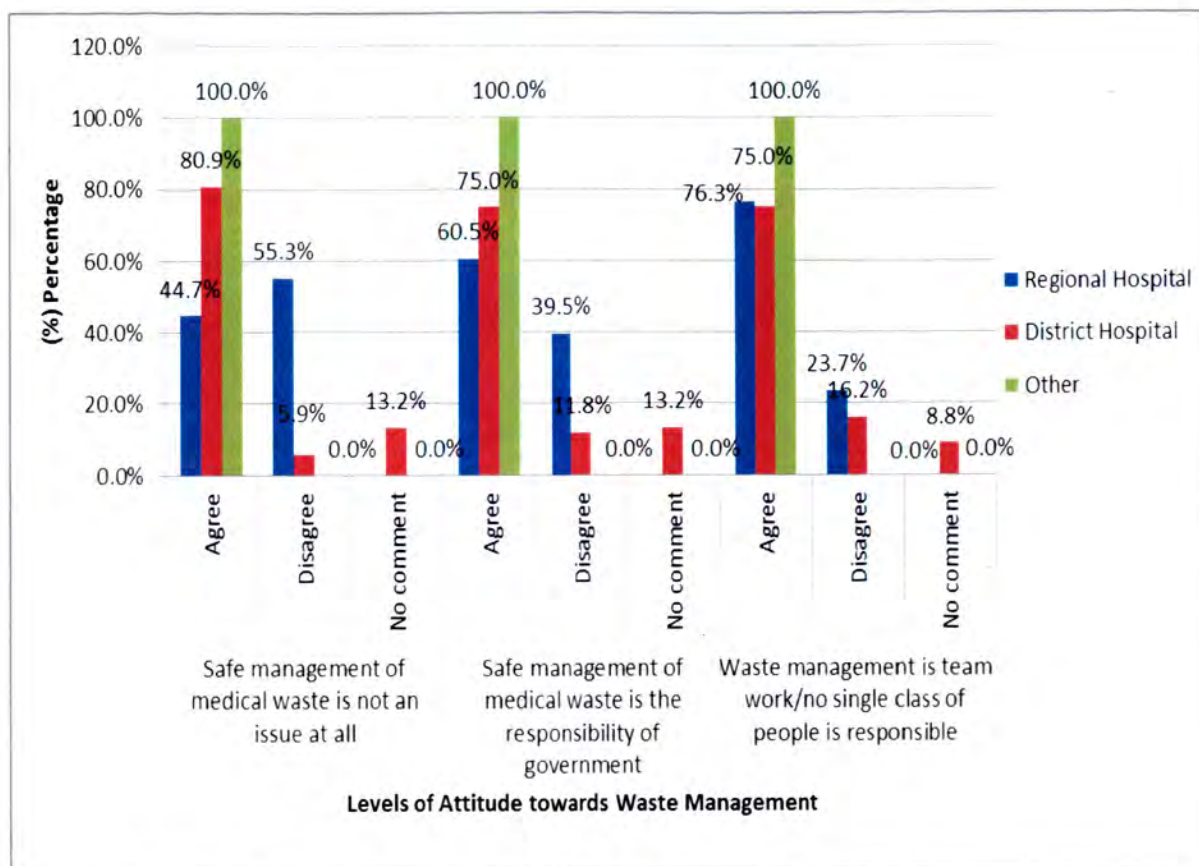


Figure 22 Levels of Attitude Assessment towards Waste Management

4.6 Hypothesis Testing

A Pearson's correlation coefficient was calculated to see if there is a relationship between the tested variables. The pairs of variables tested are: (i) volume of medical waste generated and the size of the medical facility and, (ii) the volume of medical waste generated and the frequency of incineration. The closer the correlation coefficient is to 1 the stronger the relationship. On comparing the p-value to a significance level of 0.05 (5%), it was less than 0.1 then there is a significant correlation/relationship between the variables. (Note: The values at the top are the correlation coefficients and the p-values are the ones in brackets).

On calculating a correlation coefficient between volume of waste generated and size of the facility, if the calculated value is significant then one would do the regression analysis but it was not the case. The p-value is 0.152 which is greater than 0.1. This means that there is no significant relationship between amount of waste generated and size of facility

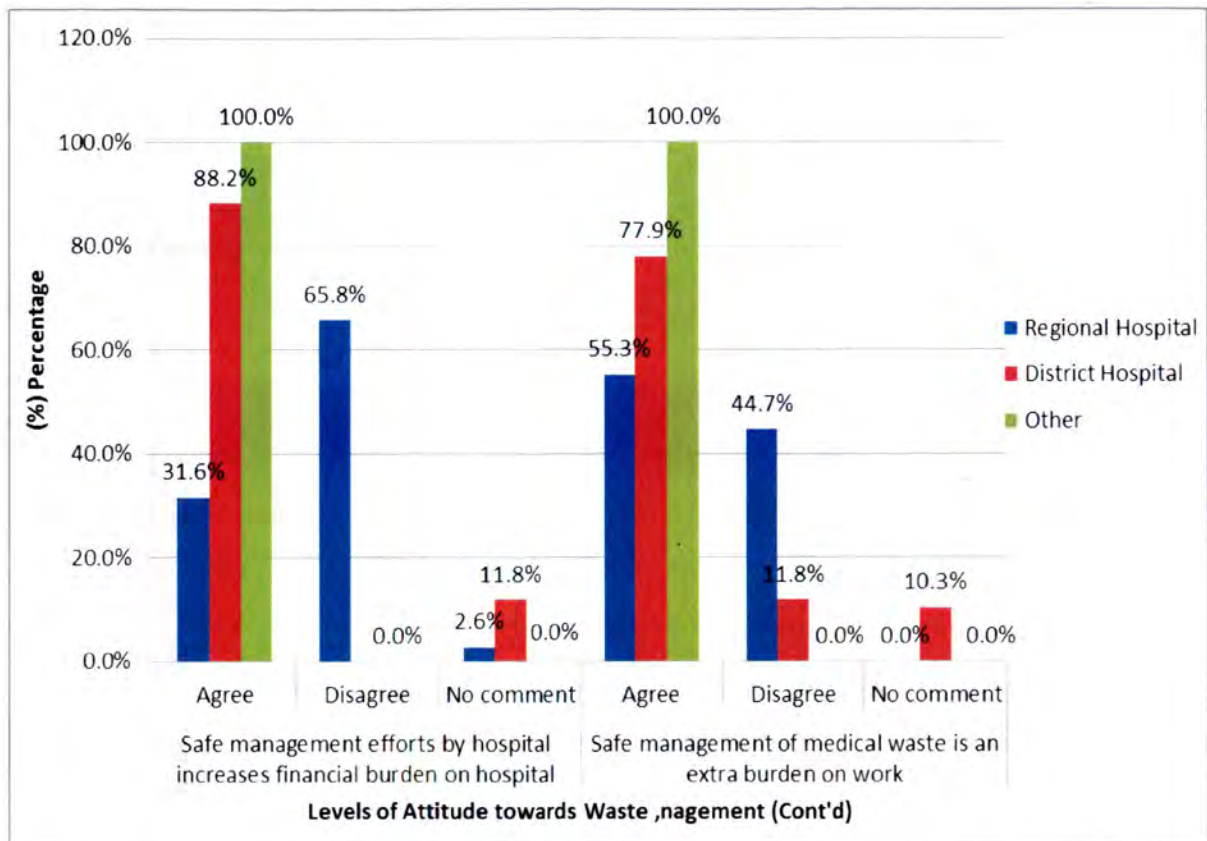


Figure 23 Levels of Attitude Assessment towards Waste Management (Cont'd)

On calculating a correlation coefficient between volume of waste accumulated and frequency of incineration (Table 13), if the calculated value is significant then one would do the regression analysis but it was not the case even in this instance. The p-value is 0.935 which is greater than 0.05. This means that there is no significant relationship between amount of waste accumulated and frequency of incineration.

Table 13 Correlation Coefficients

Variables	Size of Facility	Frequency of incineration
Waste generated	-0.118 (0.152)	-0.007 (0.935)

This section has presented results and discussion on the critical technical and managerial limitations of medical waste management. A significant number of weaknesses have been identified which need serious attention. Hypothesis testing returned a lack of statistically significant relationships meaning that the null hypothesis is accepted. On the basis of these results, objective III on technical and managerial limitations has been addressed.

4.7 Summary

The results of this research show several shortcomings in medical waste management practices. Quite notably segregation which is a key factor in waste management is not adequately done at the point of waste generation for each of the medical facilities visited in the research area. This culminates in the mixing of infectious and general waste, leading to both being collected in municipal bins. This scenario is in line with other studies (Johnson *et al.* 2013 and Offenhuber *et al.* 2013) done elsewhere. In these studies, it is highly emphasized that if there is importance of proper implementation of the procedures and good segregation practices then that forms a basis for good waste management. Results also show that there is lack of awareness regarding waste management policy. Most respondents clearly showed that they are not aware that there is a standing policy regarding waste management and only very few correctly referred to NEMA. This again is notable in other regions. Sharma *et al.* (2013a, b), Nagaraju *et al.* (2013) and Palwankar and Singh (2012) have also pointed towards lack of knowledge and awareness towards legislation on medical waste management even among qualified hospital personnel.

The results on waste disposal indicate that incineration is the overall preferred mode. It is done at different levels depending on the level of medical facility. The other option is landfilling. Landfilling is generally considered the most practical and cheapest waste management method in the study area and probably in South Africa as a whole. However,

the scarcities of available land in close proximity to areas of waste generation, as well as emissions of landfill gas (with high concentrations of methane) have made landfilling a less attractive management option (Oelofse and Nahman 2013, Demirbas 2011, Parthan *et al.* 2011). Generally, respondents showed very insufficient training from their levels of perception regarding the infectious nature of medical waste, its collection and handling, possible hazards associated with it, the risks it poses to themselves and general public and the adverse impacts it could have on the environment. Respondents pointed out the fact that medical facilities do not even have educational programmes aimed at empowering them with the necessary training to effectively address waste management issues. Training, which is effective in raising general skills and is more effective when it is associated with firm specific skills (Radha 2012, Rudraswamy *et al.* 2012, Shalini *et al.* 2012 and Srivastav *et al.* 2012), is highly lacking in all of these medical facilities visited.

There is lack of proper attitude towards medical waste. It seems to be treated very casually in the overall. The responses obtained in the study reflect the anticipated levels of waste management practices in the study area. Responses on attitude assessment are also indicative of the results obtained. Proper attitude towards one's work is a good thing because attitude and several socio-demographic characteristics have statistically different effect on work satisfaction – notably: gender; marital status; health status; age; educational level; and ethnicity (Khudiar and Raza 2013). As observed by Mohan *et al.* (2012), in relation with the effectiveness of training program and the role of support services in hospital environment, it was noted that respondents did not have better understanding, did not feel responsible in implementation of practices and lack attitude to implement this statutory requirement. Lack of understanding of the role of supportive services in the overall comprehensive health care is one of the major problems in waste management in the study area.

CHAPTER 5: DISCUSSIONS

5.1 Introduction

In chapter 4, results were presented and analysed. Following hypothesis testing, both null hypotheses were accepted indicating the absence of any statistical significance between amount of waste generated and size of facility and, between the amount of waste accumulated and frequency of incineration. In this chapter, the findings are discussed paying attention to the original research problem and to the objectives, as specified in chapter 1.

5.2 Current Medical Waste Management Practices

Waste sorting and segregation, practiced in large and specialized medical facilities to some extent, has aided substantial reductions in what would otherwise eventually end up in the waste stream. This is because no pro-active recycling of waste materials is employed. The findings reveal several flaws with regard to management policy, practices, and contributions about level of employee education and finally issues about attitude towards medical waste management. The institutional set up within which medical waste is handled and managed indicates some inherent weaknesses. These include the lack of on-going checks and balances leading to personnel implementing what practices seem best acceptable to them. No periodic staff training was reported, meaning that on-going practices may have been overtaken by recent developments. Another aspect is that though medical facilities visited form an integral part of the DOH, their remoteness in location could be placing them in a state of isolation. But, this is countered by developments in communications technology and a fairly well developed road network ensuring easy access. Therefore, if managers of these facilities claim that they are isolated, the problem may be more to do with information flows between facility and regional offices of the DOH rather than physical isolation as such.

5.3 Medical Waste Management Chain

Generally large and specialized medical facilities had better knowledge about the nature, management system and characterization of medical waste. The waste

management chain involves the collection, transport, processing, recycling or disposal, and monitoring of waste materials. Results showed that medical waste is not adequately sorted in any of the facilities in the study area. The amount of waste generated at a facility and the amount entering the waste chain should show variations if some kind of sorting was occurring at base. This is true whether in a large, district, central or smaller hospital because no effective measures are in place. Segregation was generally not perceived as a vital component of medical waste handling before the waste balance is conveyed to incinerators and/or landfills. The role of sustainable waste management is to reduce the amount of waste that is discharged into the environment by reducing the amount of waste generated. Improper waste management and disposal practices pose threats to those living in nearby communities and can result in costly clean-ups.

5.4 Operational Practices

In general, medical facilities in the area do not have a definite medical waste management policy. It was observed that there appeared to be no clear policy or plan in place for managing medical waste. Yet, the MRC and the Department of Environmental Affairs and Tourism (DEAT) have had guidelines on the handling of medical waste for several years. Whether such guidelines are made available to local managers at medical facilities is a different matter. There is no definite policy or plan for purchasing the necessary equipment and for providing the facilities for the correct management of medical waste. Most facilities have medical management guidelines prepared by supervisors but these are not strictly followed. Some facilities do not manage their medical waste properly. For instance, there is no segregation of medical waste, particularly sharps. Segregation was considered a secondary objective in the DOH and is perceived as time-consuming. Inappropriate on-site conveyances of medical waste are considered remedial measures (i.e. to minimize accumulation at points of generation and enhance or promote a clean working environment) by medical personnel involved with such inappropriate practice and are unaware of risks associated with it. From these findings, it would appear that the inspectorate division of the DOH at the district and provincial levels has not been particularly vigilant in ensuring adherence to official national guidelines. The result is that the publication of regular reports on medical waste management is not widespread. Most medical facilities do not even have regular reports about how medical waste management is

practiced. The main problems identified during the interviews are: (i) lack of necessary rules, regulations and instructions on the different aspects of collections and disposal of waste (ii) intermingling of different types of waste (i.e. hazardous and domestic hospital waste) (iii) inability to use different designated colour – coded bags thereby limiting medical waste to one collection bag (iv) absence of a dedicated waste manager such that anyone could handle medical waste (v) absence of waste management committee or team responsible for monitoring medical waste management practices and (vi) lack of education and training on medical waste management.

5.5 Managerial and Technical Limitations

This section discusses awareness of keeping records on waste generated and awareness of waste segregation practices. The waste is not properly segregated, collected and disposed of, which may lead to a negative impact on public health and on the environment. Waste generation seems to be on the increase with the advent of improving quality of life-style and common use of disposable items. The increase in the waste generation ordinarily leads to less compromised waste characterisation such that the MRW is often mixed with common MGW and disposed of as municipal waste. This was evident in the blood-soaked swabs often found in the municipal dustbins.

The following limitations were evident:

- i. Waste production: 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. However, during the interviews with waste management staff in the hospitals, the interviewees could not tell the amount of waste generated in the hospitals daily. They could also not provide information with respect to which departments generate the highest and lowest amounts of medical waste in the hospitals.

- ii. Waste segregation: The hospitals basically separate medical waste from the general waste stream at the waste production points. Therefore, they are stored and disposed of separately. However, the hospitals do not segregate medical waste 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 which is potentially a very dangerous practice. During the interviews, it was revealed that segregation of medical waste into infectious medical waste and non-infectious medical waste is not conducted according to definite rules and standards. Most hospitals did not label infectious waste with the Biohazard symbol. No control measures exist for the management of these types of waste. Separation of medical waste and general waste is however practiced to a satisfactory extent. From observations at medical facilities, it was not clear whether the problem could be located within supervision structures or simply an oversight on the part of managers. No facility, for example, reported labour shortage as a deterrent in ensuring better management practices.
- iii. From the results, on-site transport of medical waste generated in the hospitals is on a daily basis. Once collected, waste is transported to a temporary storage area by the hospital 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. The staff employed for handling waste in the hospital use almost complete personal protective equipment, including overall gowns 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 them to serious dangers. The hospitals do not maintain records or registers of medical waste collected, stored or disposed of on a daily, weekly or even monthly basis. This has serious implications for measuring the technical and managerial efficiency of the waste system.
- iv. With regard to temporary storage, each facility was observed to have on site a cordoned-off storage area for medical waste. These areas are required to be well sanitized and secured in such a way that they should be accessible only to authorized

persons. Most hospitals had a temporary collection site and variations only arose as to the safety status of such areas. It was observed during field work that in some cases the site was left unlocked and movement into and out of this storage was unregulated.

- v. Medical waste treatment on site at the individual facility leads to a reduction in volume and weight, as well as risk of infections and exposure to organic compounds of the waste. During the interviews, it was indicated that incineration is the main method for the treatment of medical waste especially infectious and sharp waste for the hospital. Autoclaves are used for treating part of the wastes.
- vi. Off-site transport of the hospital waste is undertaken by private waste management companies and waste is transported in some cases weekly from large and specialized medical facilities while small medical facilities are faced with options of having to bury or incinerate at low temperatures on their premises. This is against basic guidelines for medical waste management. Given that incinerators at these smaller facilities are not synchronized to deliver the same heating temperature levels as required by official guidelines, the practice of burying such waste poses long term environmental and health dangers. Ideally, therefore, such facilities could make arrangements for medical waste to be transported to the nearest larger medical facilities where proper infrastructures for onward transmission to official hazardous waste dumps exist. There is no reason why, given that these are public institutions, the overhead costs involved in such an arrangement cannot be factored into their normal budgeting processes. Small pickups are mainly used by the waste management companies for off-site transportation of waste. Final disposal of medical waste is done by the private waste management companies. The main treatment method used in the final disposal of infectious waste is incineration. Waste from most large hospitals is transported to an off-site area, which has been dedicated for this purpose. On the other hand smaller medical facilities often have to dispose of medical waste using land disposal methods.

Current waste management practices in the north-eastern Free State medical facilities, with the exception of large and specialised facilities, are ineffective. Observation of the waste chain at various facilities generated results which confirm this conclusion. The same

is true from responses of officials at these facilities. This cuts across waste storage, handling, collection, transportation and disposal practices. Waste is collected at the point of generation into metal dustbins, drums, plastic bins, baskets, pans, cartons, buckets, or bowls before transfer into larger or final disposal containers. Waste handlers in some facilities carry waste on shoulders or with bare hands, which indicates lack of awareness or training about potential risks involved. In contrast, large and specialised medical facilities offer pushcarts, as well as wheeled plastic bins, to facilitate easier and safer waste transfer. Disposal of most medical waste is unregulated and dealt with in a haphazard manner. Observations at some medical facilities revealed that hygienic and technical considerations were neglected or absent. For instance, in some facilities members of the public were seen scuffling through unlocked temporary storages in order to resell recyclable waste to unsuspecting poor-class patients.

The use of trained and knowledgeable personnel is central in waste management. Training of both the technical staff and the non-technical staff is critical for the proper and appropriate management of medical waste. Unfortunately, laxity and lack of adequate training and awareness in the execution of these rules leads to staid health and environment apprehension. A significant proportion of hospital waste was handled by trained personnel in large and specialized medical facilities compared to smaller facilities. The management of infectious waste was found to be normally governed by largely untrained and illiterate waste handlers from poor backgrounds. It was evident that waste handlers are not effectively trained. Where some level of training has been done or given, such programs are not periodically updated. Most waste handlers in the study area are susceptible to hazards due to lack of protective gear. In some instances the protective gear is not fully protective, which include aprons, gloves, boots and face-masks. In some cases the protective gear is worn-out and is not replaced. In other cases, waste handlers were found right inside the temporary storage facilities without being mindful that they could be exposed to syringes and other sharps. The points deliberated upon in this section are also emphasized by Lakbala and Lakbala (2013), Polan *et al.* (2013), Mohan *et al.* (2012), Singh *et al.* (2012) and Umar *et al.* (2011).

The research findings in this study share the same sentiment with that by Idowu *et al.* (2013) that strict and correct implementation of advanced and improved medical waste

management will require the involvement of accredited training centres to deliver the education and training required for staff. It is also essential that these training sessions are not merely a one-off event for individuals, but that staff is enrolled in an on-going career-based learning process. The hospital authority should make these policies more easily accessible and visible, and strive to bring training in medical waste management to their doctors. Leadership in the medical institutions should invest more in people by training staff in MW segregation. Medical institutions should provide information in the form of posters and manuals in wards and units to inform staff and the public on good practices.

The attitude of personnel in larger and specialized facilities was better towards handling medical waste as compared to those in smaller facilities. The care-free nature by personnel could also be attributed to the fact that personnel here take their placement to indicate that they are less desirable to the overall DOH as a whole. The feeling that waste management is not an important issue could also be tied to monetary (budget) allocations because it seems most facilities in the study area have budget constraints compared to performance expectations. This point was frequently touched upon during the interviews as respondents elaborated on waste management policy. Respondents were more passionate about the professional roles citing under-staffing and referred to waste management as supportive duty. Respondents were on the overall avoiding duties relating to waste management, citing lack of adequate personnel protection and, lack and/or inadequate compensation in the event of accidents. The general perception was that even if medical waste was managed appropriately there was no reward (i.e. promotional progression up the corporate ladders, monetary rewards and incentives) so there was no need to bother. Attendance of training programmes did not necessarily translate to promotion at work and upward progression. Distributions of programmes were possibly not done fairly and the basis of promoting merits hence lack of interest in other work-related programmes like waste management making professionally related courses more preferable. Regarding practices related to medical waste management, sanitary staff were ignorant on all the counts this was also observed by Shiferaw *et al.* (2012) and Mathur *et al.* (2011). All measures should be adopted to inform the public about legislation regarding medical waste management, including the risks involved in waste sorting, recycling and resale are not appreciated. This may not be easy as often it is the illiterate and very poor

people who are active in waste recycling (Sharma *et al.* 2013, Narendra *et al.* 2013, Jindal *et al.* 2012, Lakshmi and Kumar 2012, Narang *et al.* 2012).

5.6 Summary

The discussion of findings herein has indicated that the purpose of waste management is to provide sanitary living conditions to reduce the amount of matter that enters or leaves the society and encourage the reuse of matter within the society. It was also shown that on the whole large and specialized facilities have shown better management practices compared to smaller facilities though both of them are still not at the required level. Despite the efforts towards the management of waste, the current system of medical waste management in South Africa and the north-eastern Free State in particular is under development and is in dire need of immediate attention and improvement. There are fundamental problems with respect to waste management, such as a lack of a comprehensive policy and strategy, the absence of proper infrastructure, inadequate knowledge and skills of health sector personnel, and poor occupational and environmental health practices, which may lead to further deterioration of the situation if not addressed adequately.

Overall, this study set out to address four key objectives centred on operational procedures, the medical waste chain, a comparison of differences between the facilities and, technical and managerial limitations of medical waste management. The original purpose of the study was to investigate the status of medical waste management practices in the health facilities in the north eastern Free State. The study has followed the conventional steps of the scientific research process from inception, problem specification, purpose, objectives, literature survey, methods of investigation, results, analysis and discussion. The results have been reported objectively and the discussion linked to the original objectives and purpose of the study. The findings have been placed in the context of similar studies within South Africa and beyond its borders.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The findings of the study were discussed in chapter five both in terms of the objectives of the study in relation to the research problem, and in the context of the broader body of knowledge on medical waste management. This now provides a platform for drawing a conclusions and recommendations. These appear below.

6.2 Conclusions

The current practices for the handling, transportation, storage, and disposal of waste generated at the hospitals and medical laboratories needs change and major improvements. Nearly all medical facilities in the study area practice poor management of these wastes and no environmental measures or recycling programs are available. Typically, handling of the waste is assigned to poorly educated workers who perform the activities without proper training or guidance, and with insufficient protection. Poor segregation and classification procedures of the generated waste were observed at all of the surveyed hospitals and medical laboratories. The medical waste is still being dumped and mixed with domestic waste, which is collected, transported and disposed of in a similar manner as the general municipal solid waste.

The study has indicated consistent problems of management linked to inadequate training of personnel, lack of in-built incentives for staff promotion and failure to adhere to official medical waste management guidelines. It has been shown that budget allocations for medical waste handling are inadequate and that systems for on-site supervision of operations are poor and inadequate. There is lack of awareness of the need to keep records of waste generated and lack of awareness on waste segregation. Threats to both the environment and public health due to the poor handling and disposal of medical waste are noted. There are low and inadequate levels of control from the district and provincial department of health. Even allowing for variations across the study area, there is a low level of appreciation of the dangers of medical waste. But these conditions cannot be only blamed on the individual medical facilities in the study area. Although it is true that the larger facilities perform better with respect to medical waste management, what this study reveals is management failure at higher levels of the medical bureaucracy. The district and

the provincial DOH has to be held partly accountable for failing to ensure the control and regulation of medical waste management.

Medical waste must be separated from municipal waste, but in most medical facilities in the study area it tends to be collected along the rest of the waste stream. Health workers, patients and the public are at high risk due to this poor management of medical waste. Also, due to the toxic nature of medical waste, improper handling may lead to the destruction of natural environment and disturb the balance of ecosystems. This study examined the medical waste management practices in the study area. From the results of the study, it is obvious that medical waste management is not practiced according to recommended standards. There are areas where medical waste management at the hospitals is not properly done. 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 would create awareness regarding the problem of medical waste management in hospitals in the area and would generate interest for systematic control efforts for effective medical waste management.

6.3 Recommendations

There is a great need for establishing and implementing a proper medical waste management program to control and improve the existing situation in north-eastern Free State. The researcher concurs with Kumar (2012), Ojha (2011) and Sakai *et al.* (2011) that a proper waste management system is associated with the identification, reduction, storage, collection, transfer and transport, reuse and recycling, and processing and disposal of waste, keeping in view health, economics, engineering, conservation, esthetics and all other environmental conditions involved in the complete spectrum of the solution to the problem of waste. This can be addressed by increasing the awareness of managers for an effective application of the legislation, implementing realistic management programmes and providing the appropriate on-the-job training to staff members (Ndiaye *et al.* 2012). This study could help in establishing a database, information and statistics on the medical waste sources, generation, collection, transportation, treatment and disposal. Also, the study has provided suggestions for policy makers and further information to facilitate policy

development and improved medical waste management. In the light of this situation, the following recommendations are made:

- I. There is need for sustained cooperation among all key actors (government, hospitals and waste managers) in implementing a safe and reliable medical waste management strategy, not only in legislation and policy formation but also particularly in its monitoring and enforcement.
- II. There should be an obligation for each medical facility to ensure a safe and hygienic system of medical waste handling, segregation, collection, storage, transportation, treatment and disposal, with minimal risk to handlers, public health and the environment.
- III. All staff and waste handlers in each medical facility should be regularly updated with pre-employment and in-house specialized training, which provides them with a knowledge base about the process of waste management and associated health risks. The mass media could also help in sensitizing the general populous and raising their awareness level on environmental risks associated with improper management of medical waste.
- IV. Environmentally and economically sustainable technological options, which can be well operated and maintained, should be considered for medical waste management.
- V. The district and provincial DOH should exercise greater and more active control and regulation over the management of medical waste.
- VI. There is an urgent need for further studies to be conducted on other aspects of medical waste, not covered by this study, so as to generate a comprehensive pool of much-needed baseline data in the north eastern Free State, South Africa and other developing countries.

REFERENCES

- Abor, P. A. 2013. Managing Healthcare Waste in Ghana: A Comparative Study of Public and Private Hospitals. *International Journal of Health Care Quality Assurance* **26** (4): 6 - 6.
- Abor, Patience Aseweh, Medical waste management at Tygerberg hospital in the Western Cape, South Africa. *CPUT Theses & Dissertations*. Paper 52. Accessed on January 16, 2012 from http://dk.cput.ac.za/td_cput/52
- Achillas, C., Moussiopoulos, N., Karagiannidis, A., Baniyas, G. and Perkoulidis, G. 2013. The use of multi-criteria decision analysis to tackle waste management problems: a literature review. *Waste Management & Research* **31** (2) 115 – 129.
- Achillas, C., Vlachokostas, N. Moussiopoulos, G. Perkoulidis, G. Baniyas, and M. Mastropavlos. 2011. Electronic Waste Management Cost: a Scenario-based Analysis for Greece. *Waste Management & Research* **29** (9): 963 - 972.
- Afon, A., 2012. A survey of operational characteristics, socioeconomic and health effects of scavenging activity in Lagos, Nigeria. *Waste Management and Research* **30** (7): 664 - 671.
- Agamuthu, P. 2013. Landfilling in developing countries. *Waste Management and Research* **31**(1) 1 - 2.
- Agamuthu, P. and Fauziah, S.H., 2011. Pharmaceuticals in the environment, a prescription for disaster? *Waste Management and Research* **29** (4): 349 - 350.
- Agar, J. W. 2012. Personal viewpoint: Hemodialysis—Water, power, and waste disposal: Rethinking our environmental responsibilities. *Hemodialysis International* **16** (1): 6 - 10.
- Agar, J. W. M., Perkins, A. and Tjipto, A. 2012. Solar-Assisted Hemodialysis. *Clinical Journal of the American Society of Nephrology* **7** (2): 310 - 314.
- Aghapour, P., Nabizadeh, R., Nouri, J., Monavari, M. and Yaghmaeian, K. 2013. Analysis of the health and environmental status of sterilizers in hospital waste management: a case study of hospitals in Tehran. *Waste Management & Research* **0** (0): 1 – 5.
- Aguayo-Villarreal, I. A., Bonilla-Petriciolet, A., Hernández-Montoya, V., Montes-Morán, M. A. and Reynel-Avila, H. E. 2011. Batch and column studies of Zn²⁺ removal from aqueous solution using chicken feathers as sorbents. *Chemical Engineering Journal* **167** (1): 67 - 76.
- Akbolat, M., Dede, C. Isik, O. and Saglam, H. 2011. Medical Waste Management Practices in Turkey: A Case Study in Sakarya. *Pakistan Journal of Medical Sciences* **27** (4): 892 - 895.
- Akinci, G., Guven, E.D. and Gok, G. 2012. Evaluation of waste management options and resource conservation potentials according to the waste characteristics and household income: A case study in Aegean Region, Turkey. *Resources, Conservation and Recycling* **58**: 114 - 124.

- Aksakal, F. N., Aras, İlhan, E. M. and Aycan, S. 2011. Medical Waste Survey in a University Hospital: Do Intern Doctors and Emergency Nurses Know and Pay Attention to Segregation of Wastes? *Survival and Sustainability*: 245 - 252.
- Al Sabbagh, M. K., Velis, C. Wilson, D. C. and Cheeseman, C. 2012. Resource Management Performance in Bahrain: a Systematic Analysis of Municipal Waste Management, Secondary Material Flows and Organizational Aspects. *Waste Management & Research* **30** (8): 813 - 824.
- Alavi, N., Goudarzi, G., Babaei, A. A., Jaafarzadeh, N. and Hosseinzadeh, M. 2013. Municipal solid waste landfill site selection with geographic information systems and analytical hierarchy process: a case study in Mahshahr County, Iran. *Waste Management and Research* **31** (1): 98 – 105.
- Al-Emad, A. A. 2011. Assessment of Medical Waste Management in the Main Hospitals in Yemen. *Eastern Mediterranean Health Journal* **17** (10): 730 – 737.
- Al-Khatib, I. A., Abu-Dayah, M., Hajjeh, H. and Al-Shanbleh, T. 2011. Solid Medical Waste Management in Healthcare Centers in Palestine. *Survival and Sustainability*: 545 - 555.
- Al-Maaded, M., Madi, N. K., Kahraman, R., Hodzic, A. and Ozerkan, N. G. 2012. An Overview of Solid Waste Management and Plastic Recycling in Qatar. *Journal of Polymers and the Environment*: 1 - 9.
- Alslaibi, T.M., Abustan, I., Mogheir, Y.K. and Afifi, S. 2013. Quantification of leachate discharged to groundwater using the water balance method and the Hydrologic Evaluation of Landfill Performance (HELP) model. *Waste Management & Research* **31** (1) 50 - 59.
- Ambashta, R. D. and Sillanpää, M. E. T. 2011. Membrane Purification in Radioactive Waste Management: a Short Review. *Journal of Environmental Radioactivity*. **105**: 76 - 84.
- Anagaw, B., Shiferaw, Y., Anagaw, B., Belyhun, Y., Erku, W., Biadgelegn, F., Moges, B., Alemu, A., Moges, F. and Mulu, A. 2012. Seroprevalence of Hepatitis B and C Viruses among Medical Waste Handlers at Gondar Town Health Institutions, Northwest Ethiopia. *BMC Research Notes* **5** (1): 55.
- Arora, L. and Agarwal, S. 2011. Knowledge, Attitude and Practices regarding Waste Management in Selected Hostel Students of University of Rajasthan, Jaipur. *International Journal of Chemical, Environmental and Pharmaceutical Research* **2** (1): 40 - 43.
- Askarian, M., Motazedian, N. and Palenik, C. J. 2012. Clinical laboratory waste management in Shiraz, Iran. *Waste Management and Research* **30** (6): 631 - 634.
- Astrup, T., Riber, C. and Pedersen, A. J. 2011. Incinerator performance: effects of changes in waste input and furnace operation on air emissions and residues. *Waste Management & Research* **29** (10 suppl): S57 - S68.

- Basu, M., Das, P. and Pal, R. 2012. Assessment of future physicians on biomedical waste management in a tertiary care hospital of West Bengal. *Journal of Natural Science, Biology, and Medicine* **3**(1): 38.
- Bazrafshan, E. and Mostafapoor, F. K. 2011. Survey of medical waste characterization and management in Iran: a case study of Sistan and Baluchestan Province. *Waste Management & Research* **29** (4): 442 - 450.
- Bella, V. D., Mansoor, A. and Mentore, V. 2012. Constraints to healthcare waste treatment in low-income countries – a case study from Somaliland. *Waste Management & Research* **30** (6): 572 - 575.
- Berwick, D. M. and Hackbarth, A. D. 2012. Eliminating Waste in US Health Care. *JAMA: The Journal of the American Medical Association* **307** (14): 1513 - 1516.
- Bhaskar, B., Nidugala, H. and Avadhani, R. 2012. Biomedical Waste Management–knowledge and Practices among Healthcare Providers in Mangalore. *Methodology. Nitte University Journal of Health Science* **2** (1): 35 – 36.
- Botelho, A. 2012. The impact of education and training on compliance behaviour and waste generation in European private healthcare facilities. *Journal of Environmental Management* **98**: 5 - 10.
- Brook, R.H., 2011. The role of physicians in controlling medical care costs and reducing waste. *JAMA: The Journal of the American Medical Association* **306** (6): 650.
- Brown, C., Milke, M. and Seville, E. 2011: Disaster waste management: A review article. *Waste management* **31** (6): 1085 - 1098.
- Centre for Disease Control and Prevention. Guidelines for environmental infection control in Health-care facilities: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). *MMWR* 2003; 52 (No: RR-10): 1 - 48.
- Chai, X., Hao, Y., Shimaoka, T., Nakayama, H., Komiya, T. and Zhao, Y. 2013. The effect of aeration position on the spatial distribution and reduction of pollutants in the landfill stabilization process—a pilot scale study. *Waste Management & Research* **31** (1): 41 - 49.
- Chancerel, P., Bolland, T. and Rotter, V. S. 2011. Status of Pre-processing of Waste Electrical and Electronic Equipment in Germany and Its Influence on the Recovery of Gold. *Waste Management & Research* **29** (3): 309 - 317.
- Chang, C. P., Shen, Y.H., Chou, I., Wang, Y.F., Kuo, Y.M. and Chang, J.E. 2012. Metal Distribution Characteristics in a Laboratory Waste Incinerator. *Aerosol and Air Quality Research* **12**: 426 - 434.

- Chi, N. K. and Long, P. Q. 2011. Solid Waste Management Associated with the Development of 3R Initiatives: Case Study in Major Urban Areas of Vietnam. *Journal of Material Cycles and Waste Management* **13** (1): 25 - 33.
- Chima, G. N., Ezekwe, I. C. and Digba, N. O. 2011. An Assessment of Medical Waste Management in Health Institutions in Yenagoa, South-South, Nigeria. *World Review of Science, Technology and Sustainable Development* **8** (2): 224 - 233.
- Chowdhury, A. K. A., Roy, T., Faroque, A. B. M., Bachar, S., Asaduzzaman, M., Nasrin, N. Akter, N. 2011. A Comprehensive Situation Assessment of Injection Practices in Primary Health Care Hospitals in Bangladesh. *BMC Public Health* **11** (1): 779.
- Ciplak, N. and Barton J. R. 2012. A System Dynamics Approach for Healthcare Waste Management: a Case Study in Istanbul Metropolitan City, Turkey. *Waste Management & Research* **30** (6): 576 - 586.
- Dana, T. 2011. Hospital Waste Management: Bangladesh. *International Journal of Sustainable Development* **2**(9): 29 - 40.
- DEAT (South African Department of Environmental Affairs and Tourism). 1999. National Waste Management Strategies and Action Plans. Retrieved on 12 May 2012 from the Website, <http://www.environment.gov.za/ProjProg/Waste-Mgmt/waste.html>
- DEAT (South African Department of Environmental Affairs and Tourism). 2004. Guidelines for the Design, Installation, and Operation of Incinerators. Air Pollution Prevention Act of 1965, 2nd Schedule Process 39, Pretoria, South Africa. Retrieved on 12 May 2012 from the Website, <http://www.environment.gov.za>
- DEAT (South African Department of Environmental Affairs and Tourism). 2005. National Waste Management Strategy Implementation Project. Department of Environmental Affairs and Tourism. Pretoria.
- DEAT (South African Department of Environmental Affairs and Tourism). 2007. National Environmental Management Waste Act, 2008 (Act 59 of 2008). Government Printer, Pretoria.
- Demirbas, A. 2011. Waste Management, Waste Resource Facilities and Waste Conversion Processes. *Energy Conversion and Management* **52** (2): 1280 - 1287.
- Diaz R. and Otoma, S. 2013. Constrained recycling: a framework to reduce landfilling in developing countries. *Waste Management & Research* **31** (1) 23 - 29.
- Díaz, M. J., Martínez, E., Piñeiro, C., Palavecinos, M., Benayas, J. and Toribio, A. M. 2012. Involvement of citizens in hazardous waste management and use of recycling centres in the city of Madrid (Spain). *Waste Management and Research* **30** (7): 689 - 699.

- DOH (South African Department of Health). 1996. Implementation of the national health system. Retrieved on 12 May 2012 from the Website, <http://www.doh.gov.za>
- Doona, C., Curtin, M., Feeherry, F., Kandilikar, S., Baer, D., Kustin, K., Taub, I. and McManus, A. 2012. Portable chemical sterilizer. U.S. Patent No. 7,883,640. Washington, DC: U.S. Patent and Trademark Office.
- Du, Y., Jin, Y., Lu, S., Peng, Z., Li, X. and Yan, J. 2013 Study of PCDD/Fs distribution in fly ash, ash deposits, and bottom ash from a medical waste incinerator in China, *Journal of the Air & Waste Management Association* **63** (2): 230 - 236.
- Dursun, M., Karsak, E. E. and Karadayi, M. A. 2011a. A Fuzzy MCDM Approach for Health-Care Waste Management. *World Academy of Science, Engineering and Technology* **73**: 858 – 864.
- Dursun, M., Karsak, E. E. and Karadayi, M. A. 2011b. A fuzzy multi-criteria group decision making framework for evaluating health-care waste disposal alternatives. *Expert Systems with Applications* **38** (9): 11453 - 11462.
- Dursun, M., Karsak, E. E. and Karadayi, M. A., 2011c. Assessment of health-care waste treatment alternatives using fuzzy multi-criteria decision making approaches. *Resources, Conservation and Recycling* **57**: 98 - 107.
- Eker, H. H. and Bilgili, M. S. 2011. Statistical analysis of waste generation in healthcare services: a case study. *Waste Management & Research* **29** (8): 791 - 796.
- Elimelech, E., Ayalon, O. and Flicstein, B. 2011. Hazardous Waste Management and Weight-based indicators - The Case of Haifa Metropolis. *Journal of Hazardous Materials* **185** (2): 626 - 633.
- Fadipe, O. O., Oladepo, K. T., Jeje, J. O. and Ogedengbe, M. O. 2012. Characterization and analysis of medical solid waste in Osun State, Nigeria. *African Journal of Environmental Science and Technology* **5** (12): 1027 - 1038.
- Faisal, M. N., Khan, S. and Farooqi, I. H. 2011. An Analytic Process Model for Selection of Infectious Waste Management Contractors. *International Journal of Mathematics in Operational Research* **3** (4): 359 - 376.
- Farzadkia, M., Jorfi, S., Akbari, H. and Ghasemi, M. 2012. Evaluation of dry solid waste recycling from municipal solid waste: case of Mashhad city, Iran. *Waste Management & Research* **30** (1): 106 - 112.
- Ferdowsi, A., Ferdosi, M., Mehrani, Z. and Narenjkar, K. 2012. Certain Hospital Waste Management Practices in Isfahan, Iran. *International Journal of Preventive Medicine* **3**(3)(S): 176 – 185.
- Forouhar, A. and Hristovski, K. D. 2012. Characterization of the municipal solid waste stream in Kabul, Afghanistan. *Habitat International* **36** (3): 406 – 413.

- Fraiwan, L. A., Lweesy, K., Oweis, R., Qablan, H. A. and Hasanat, M. 2013. Medical waste management practices in southern Jordan. *International Journal of Environment and Waste Management* **11** (3): 255 - 266.
- Gavrancic, T., Simic, A. and Gavrancic, B. 2012. Medical waste management at the Oncology Institute of Vojvodina: possibilities of successful implementation of medical waste regulation in Serbia. *Waste Management & Research* **30** (6): 596 - 600.
- Geng, J., Lu, Y., Ren, B. and Wang, T. 2011. Knowledge, attitude and practices toward dioxins in China's waste incineration industry and coking industry. *International Journal of Environment and Pollution* **45** (4): 385 - 402.
- Geng, Y., Ren, W. X., Xue, B., Fujita, T., Xi, F., Liu, Y. and Wang, M. 2013. Regional medical waste management in China: a case study of Shenyang. *Journal of Material Cycles and Waste Management* **1** - 11.
- Gerba, C. P., Tamimi, A. H., Pettigrew, C., Weisbrod, A. V. and Rajagopalan, V. 2011. Sources of Microbial Pathogens in Municipal Solid Waste Landfills in the United States of America. *Waste Management & Research* **29** (8): 781 - 790.
- Gilley, D. B. and Holmberg, O. 2013. Addressing patient safety through the use of 'criteria of acceptability' for medical radiation equipment. *Radiation Protection Dosimetry* **153** (2): 155 - 157.
- Godfrey, L. and Scott, D. 2011. Improving Waste Management through a Process of Learning: The South African Waste Information System. *Waste Management & Research* **29** (5): 501 - 511.
- Goorhuis, M., Reus, P., Nieuwenhuis, E., Spanbroek, N., Sol, S. and van Rijn, J. 2012. New developments in waste management in the Netherlands. *Waste Management & Research* **30** (9) Supplement: 67 – 77.
- Grimmond, T. and Reiner, S. 2012. Impact on Carbon Footprint: a Life Cycle Assessment of Disposable versus Reusable Sharps Containers in a Large US Hospital. *Waste Management & Research* **30** (6): 639 - 642.
- Gupta, N., Goswami, B., Singh, B. and Ghosh, S. 2012. Awareness about HIV infection among the paramedical staff in a tertiary care hospital in Delhi, India. *Clinics and Practice* **2** (1): e13.
- Habib, M., Miles, N. J. and Hall, P. 2013. Recovering metallic fractions from waste electrical and electronic equipment by a novel vibration system. *Waste Management* **33**: 722 – 729.
- Hamasuna, R., Takahashi, S., Yamamoto, S., Arakawa, S., Yanaihara, H., Ishikawa, S. and Matsumoto, T. 2011. Guideline for the Prevention of Health Care-associated Infection in Urological Practice in Japan. *International Journal of Urology* **18** (7): 495 - 502.

- Hassanvand, M. S., Naddafi, K., Nabizadeh, R., Momeniha, F., Mesdaghinia, A. and Yaghmaeian, K. 2011. Hazardous Waste Management in Educational and Research Centers: a Case Study. *Toxicological & Environmental Chemistry* **93** (8): 1636 - 1642.
- Hatami-Marbini, A., Tavana, M., Moradi, M. and Kangi, F. 2013. A fuzzy group Electre method for safety and health assessment in hazardous waste recycling facilities. *Safety Science* **51**: 414 - 426.
- Haylamicheal, I. D. and Desalegne, S. A. 2012. A review of legal framework applicable for the management of healthcare waste and current management practices in Ethiopia. *Waste Management & Research* **30** (6): 607 - 618.
- Haylamicheal, I. D., Dalvie, M. A., Yirsaw, B. D. and Zegeye, H. A. 2011. Assessing the Management of Healthcare Waste in Hawassa City, Ethiopia. *Waste Management & Research* **29** (8): 854 - 862.
- Hinton, T.G., Garnier-Laplace, J., Vandenhove, H., Dowdall, M., Adam-Guillermin, C., Alonzo, F., Barnett, C., Beaugelin-Seiller, K., Beresford, N. A., Bradshaw, C., Brown, J., Eyrolle, F., Fevrier, L., Gariel, J.C., Gilbin, R., Hertel-Aas, T., Horemans, N., Howard, B.J., Ikäheimonen, G.T., Mora, J. C., Oughton, D., Real, A., Salbu, B., Simon-Cornu, M., Steiner, M., Sweeck, L. and Vives Batlle, J. 2013. An invitation to contribute to a strategic research agenda in radioecology. *Journal of Environmental Radioactivity* **115**: 73 - 82.
- Hiyama, A., Nohara, C., Kinjo, S., Taira, W., Gima, S., Tanahara, A. and Otaki, J.M. 2012. The biological impacts of the Fukushima nuclear accident on the pale grass blue butterfly. *Scientific Reports* **2**: 570.
- Ho C. C. and Liao, C. J. 2011. The use of failure mode and effects analysis to construct an effective disposal and prevention mechanism for infectious hospital waste. *Waste Management* **31**: 2631 - 2637.
- Hossain, M. S., Balakrishnan, V., Rahman, N. N. A., Sarker, M. Z. I. and Kadir, M. O. A. 2012. Treatment of Clinical Solid Waste Using a Steam Autoclave as a Possible Alternative Technology to Incineration. *International Journal of Environmental Research and Public Health* **9** (3): 855 - 867.
- Hossain, M. S., Santhanam, A., Nik Norulaini, N. S. and Omar, A. K. 2011. Clinical Solid Waste Management Practices and Its Impact on Human Health and environment – A Review. *Waste Management* **31** (4): 754 - 766.
- Hossain, S., Rahman, N. N. A., Balakrishnan, V., Puvanesuaran, V. R., Sarker Z. I. and Kadir, M. O. A. 2013. Infectious Risk Assessment of Unsafe Handling Practices and Management of Clinical Solid Waste. *International Journal of Environmental Research and Public Health* **10**: 556 - 567.

- Idoko, O. M., Ologunorisa, T. E. and Okoya, A. A. 2012. Temporal Variability of Heavy Metals Concentration in Rural Groundwater of Benue State, Middle Belt, Nigeria. *Journal of Sustainable Development* **5** (2): 1 – 16.
- Idowu, I. A., Alo, B. and Atherton, W. 2013. Profile of medical waste management in two healthcare facilities in Lagos, Nigeria: a case study. *Waste Management & Research* **0** (0): 1 – 8.
- International Committee of the Red Cross. 2011. Medical Waste Management. Geneva. Switzerland.
- Jabbari, H., Farokhfar, M., Asghari Jafarabadi, M., Taghipour, H., Bakhshian, F. and Rohane, S. 2012. Personal and organizational predictors of physicians' knowledge, attitudes and practices related to medical waste management in Mazandaran province. *Waste Management & Research* **30** (7): 738 - 744.
- Ji, H., Zhang, L., Liu, S., Qu, X., Zhang, C. and Gao, J. 2012. Optimization of microbial inactivation of shrimp by dense phase carbon dioxide. *International Journal of Food Microbiology* **156**: 44 - 49.
- Jiburum, B. C. and Jiburum, U. 2012. An appraisal of medical waste management in four tertiary hospitals in Enugu, Nigeria. *Port Harcourt Medical Journal* **6** (2): 192 - 197.
- Jindal, A. K., Gupta, A., Grewal, V. S. and Mahen, A. 2012. Biomedical waste disposal in Armed Forces: A systems analysis. *Medical Journal Armed Forces India* **1** – 6.
- Johnson, K. M., Gonzalez, M. L., Dueñas, L., Gamero, M., Relyea, G., Luque, L. E. and Caniza, M. A. 2013. Improving waste segregation while reducing costs in a tertiary-care hospital in a lower-middle-income country in Central America. *Waste Management & Research* **0** (0): 1 - 6.
- Johnson, O. 2012. A statistical analysis of medical waste generation, management and the health implications: A case study of Enugu metropolis, Enugu state, Nigeria. *Continental Journal of Applied Sciences* **6** (1): 25 - 30.
- Kagonji, I. S. and Manyele, S. V. 2011. Analysis of the measured medical waste generation rate in Tanzanian district hospitals using statistical methods. *African Journal of Environmental Science and Technology* **5** (10): 815 – 833.
- Kakizaki, M., Ikeda, N., Ali, M., Enkhtuya, B., Tsolmon, M., Shibuya, K. and Kuroiwa, C. 2011. Needlestick and Sharps Injuries among Health Care Workers at Public Tertiary Hospitals in an Urban Community in Mongolia. *BMC Research Notes* **4** (1): 184.
- Karliner, J., and Orris, P. 2011. Global Substitution of Mercury-Based Medical Devices in the Health Sector. *Water and Sanitation-Related Diseases and the Environment*: 351 - 358.
- Katusiimeh, M. W., Burger, K. and Mol, A. P. J. 2013. Informal waste collection and its co-existence with the formal waste sector: The case of Kampala, Uganda. *Habitat International* **38**: 1 - 9.

- Khammaneechan, P., Okanurak, K., Sithisarankul, P., Tantrakarnapa, K. and Norramit, P. 2011. Effects of an incinerator project on a healthcare-waste management system. *Waste Management & Research* **29**(10 suppl): S91–S96.
- Khan, S., Cao, Q., Zheng, Y. M. Huang, Y. Z. and Zhu, Y. G. 2008: Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution* **152**: 686 – 692.
- Khetriwal, D. S., Widmer, R., Kuehr, R. and Huisman, J. 2011. One WEEE, Many Species: Lessons from the European Experience. *Waste Management & Research* **29** (9): 954 - 962.
- Khudair, I. F. and Raza, S. A. 2013. Measuring patients' satisfaction with Qatar hospital pharmacy services. *International Journal of Health Care Quality Assurance* **26** (5): 1 – 24.
- Kim, J. Y., Dzik, W. H., Dighe, A. S. and Lewandrowski K. B. 2011. Utilization Management in a Large Urban Academic Medical Center A 10-Year Experience. *American Journal of Clinical Pathology* **135** (1): 108 - 118.
- Kinnarinen, T., Huhtanen, M., Penttilä, M. and Häkkinen, A. 2013. Removal of chloride from fly ash produced in hazardous waste incineration by leaching and displacement washing in a vertical filter press. *Waste Management & Research* **31** (2): 178 - 186.
- Kishore, J., Rojha, R. B., Routray, D. and Basandra, S. 2012. Awareness about Environmental Health among Nursing Personnel in Delhi. *Journal of Nursing Science & Practice* **2** (1): 1 – 8.
- Komilis, D., Fouki, A. and Papadopoulos, D. 2012. Hazardous Medical Waste Generation Rates of Different Categories of Health-care Facilities. *Waste Management* **32**: 1434 – 1441.
- Komilis, Dimitrios, Katsafaros, N. and Vassilopoulos, P., 2011. Hazardous medical waste generation in Greece: case studies from medical facilities in Attica and from a small insular hospital. *Waste Management & Research* **29** (8): 807 - 814.
- Koolivand, A., Mahvi, A.H., Alipoor, V., Azizi, K. and Binavapour, M. 2012. Investigating composition and production rate of healthcare waste and associated management practices in Bandar Abbass, Iran. *Waste Management & Research* **30** (6): 601 - 606.
- Kühling, J. G. and Pieper, U. 2012. Management of healthcare waste: developments in Southeast Asia in the twenty-first century. *Waste Management & Research* **30** (9 suppl): 100 - 104.
- Kumar, A. H. S. 2012. Effectively Communicating the 5R's (replace, Reduce, Refine, Reuse, and Rehabilitate) of Research Ethics, Biomedical Waste, Personalized Medicines and the Rest. *Journal of Natural Science, Biology, and Medicine* **3** (1): 1.
- Kuo, Y. C. 2011. Providing sound recommendations on hazardous emissions during E-waste management: Reducing adverse human and environmental health effect in Taiwan Duke University. (Doctoral Dissertation, Duke University).

- Kutu, F. R., Muchaonyerwa, P. and Mnkeni, P. N., 2011. Complementary nutrient effects of separately collected human faeces and urine on the yield and nutrient uptake of spinach (*Spinacia oleracea*). *Waste Management & Research* **29** (5): 532 - 539.
- Lakbala, P. and Lakbala, M. 2013. Knowledge, attitude and practice of hospital staff management. *Waste Management & Research* **0**(0): 1 - 4.
- Lakbala, P., Azar, F. E. and Kamali, H. 2012. Needlestick and Sharps Injuries among Housekeeping Workers in Hospitals of Shiraz, Iran. *BMC Research Notes* **5** (1): 276.
- Lakshmi, B. S. and Kumar, M. P. 2012. Awareness about Bio-Medical Waste Management among Health Care Personnel of Some Important Medical Centres in Agra. *International Journal of Engineering* **1** (7): 1 – 5.
- Lau, M. H. Y., Leung, K. M. Y., Wong, S. W. Y., Wang, H. and Yan, Z. G. 2012. Environmental policy, legislation and management of persistent organic pollutants (POPs) in China. *Environmental Pollution* **165**: 182 - 192.
- Lekwot, V. E., Nunyi, B. V., Ifeany, E., Christian, O. and Adamu, B. 2012. Public health implication of improper hospital waste disposal in Zonkwa district of Zangon-kataf local government area, Kaduna state. *Journal of Research in Environmental Science and Toxicology* **1**(2): 023 - 028.
- Liu, G., Zheng, M., Cai, Z., Wu, Y. and Jiang, G. 2013. Dioxin analysis in China. *Trends in Analytical Chemistry. Trends in Analytical Chemistry* **46**: 178 – 188.
- Liu, Q., Shi, S. J., Du, L. Q., Wang, Y., Cao, J., Xu, C., Fan, F. Y., Giesy, J. P. and Hecker, M. 2012. Environmental and Health Challenges of the Global Growth of Electronic Waste. *Environmental Science and Pollution Research*: 1 - 3.
- Longe, E. O. 2012. Healthcare waste management status in Lagos State, Nigeria: a case study from selected healthcare facilities in Ikorodu and Lagos metropolis. *Waste Management & Research*: **30** (6): 562 - 571.
- Ma, P., Ma, Z., Yan, J., Chi, Y., Ni, M. and Cen, K. 2011. Industrial Hazardous Waste Treatment Featuring a Rotary Kiln and Grate Furnace Incinerator: a Case Study in China. *Waste Management & Research* **29** (10): 1108 - 1112.
- Madhukumar, S. and Ramesh, G. 2012. Study about awareness and practices about health care waste management among hospital staff in a medical college hospital, Bangalore. *International Journal of Basic Medical Science* **3** (1): 7 – 11.
- Magnani, C. 1997. The Piedmont Childhood Cancer Registry. Incidence of childhood cancers: comparison between the specialized registry of Piedmont and the General Italian Registries. In: R. Zanetti, P. Crosignani and S. Rosso (eds.), *Cancer in Italy*, pp. 351–362, Il Pensiero Scientifico, Rome.

- Mandal, S., Ruggles, R., Leonardi, G., Goodfellow, F., Bradley, N. and Murray, V. 2011. Developing Best Practice Response to Carbon Monoxide Incidents: A Toolkit for Health Protection Frontline Staff. *Public Health* **125** (3): 148 - 156.
- Manga, V. E., Forton, O. T., Mofor, L. A. and Woodard, R. 2011. Health Care Waste Management in Cameroon: A Case Study from the South-western Region. *Resources, Conservation and Recycling* **57**: 108 - 116.
- Mangizvo, R. V. and Wiseman, M. 2012. The Management, Practice and Environmental Health Implications of the Municipal Solid Waste Dump Site in Alice, South Africa. *Online Journal of Social Sciences Research* **1** (5): 125 - 131.
- Manhart, A. 2011. International Cooperation for Metal Recycling From Waste Electrical and Electronic Equipment. *Journal of Industrial Ecology* **15** (1): 13 - 30.
- Mannion, R. 2011. General Practitioner-led Commissioning in the NHS: Progress, Prospects and Pitfalls. *British Medical Bulletin* **97** (1): 7 - 15.
- Mathur, V., Dwivedi, S., Hassan M. A. and Misra, R. P. 2011. Knowledge, attitude, and practices about biomedical waste management among healthcare personnel: A cross-sectional study. *Indian Journal of Community Medicine* **36**: 143 - 145.
- Mathur, P., Patan, S. and Shobhawat, A. S. 2012. Need of Biomedical Waste Management System in Hospitals - An Emerging issue - A Review. *Current World Environment* **7** (1): 117 - 124.
- Mihailidou, E. K., Antoniadis, K. D. and Assael, M. J. 2012. The 319 Major Industrial Accidents since 1917. *International Review of Chemical Engineering* **4** (6): 529 - 540.
- Miller, V. B., Miginsky, C. S. and Connelly, N. C. 2012. The Risk Manager's Contribution to Patient Safety and Risk Management in the Ambulatory or Physician Practice Setting. *Journal of Healthcare Risk Management* **31** (4): 31 - 39.
- Mochungong, P. I. K., Gulis, G. and Sodemann, M. 2011a. Clinical Waste Incinerators in Cameroon - a Case Study. *International Journal of Health Care Quality Assurance* **25** (1): 1 - 1.
- Mochungong, P. I. K., Gulis, G. and Sodemann, M. 2011b. Morbidity among Children Living Around Clinical Waste Treatment and Disposal Site in the Northwest Region of Cameroon. *Journal of Public Health in Africa* **2** (1): e13.
- Mohamed, A. F., Hadi, A. S. Idrus, S. and Shah, A. H. H. 2011. Ecological Transition: From the End-of-pipe to Ecosystem Approach for Waste Management in Malaysian City. *Akademika* **81** (2): 71 - 78.
- Mohan, D. R., Prasad, M. V. and Kumar, K. S. 2012. Impact of training on bio medical waste management - A study and analysis. *EXCEL International Journal of Multidisciplinary Management Studies* **2** (6): 69 - 80.

- Mohankumar, S. 2012. Hospital Waste Management and Environmental Problems in India. *International Journal of Pharmaceutical & Biological Archive*, 2(6).
- Mohankumar, S. and Kottaiveeran, K. 2012. Hospital Waste Management and Environmental Problems in India. Review Article. *International Journal of Pharmaceutical & Biological Archives* 2 (6): 1621 - 1626.
- Montoneri, E., Boffa, V., Savarino, P., Perrone, D., Ghezzi, M., Montoneri, C. and Mendichi, R. 2011. Acid soluble bio-organic substances isolated from urban bio-waste. Chemical composition and properties of products. *Waste Management* 31: 10 - 17.
- Morenikeji, O. A. 2011. An Investigation of the Disposal of Dental Clinical Waste in Ibadan City, South-west Nigeria. *Waste Management & Research* 29 (3): 318 - 322.
- Muduli, K. and Barve, A. 2012. Barriers to Green Practices in Health Care Waste Sector: An Indian Perspective. *International Journal of Environmental Science and Development* 3 (4): 393 - 399.
- Mugambe, R. K., Ssempebwa, J. C. Tumwesigye, N. M., van Vliet, B. and Adedimeji, A. 2011. Healthcare Waste Management in Uganda: Management and Generation Rates in Public and Private Hospitals in Kampala. *Journal of Public Health*: 1 - 7.
- Murthy, P. G., Leelaja, B. C. and Hosmani, S. P. 2011. Bio-medical wastes disposal and management in some major hospitals of Mysore City, India. *International NGO Journal* 6 (3): 071 - 078.
- Musee, N. 2011. Nanowastes and the Environment: Potential New Waste Management Paradigm. *Environment International* 37 (1): 112 - 128.
- Nabizadeh, R., Koolivand, A., Jafari, A.J., Yunesian, M. and Omrani, G. 2012. Composition and production rate of dental solid waste and associated management practices in Hamadan, Iran. *Waste Management & Research* 30 (6): 619 - 624.
- Nagaraju, B., Padmavathi, G. V., Puranik, D. S., Shantharaj, M. P. and Sampulatha, S. P. 2013. A study to assess the knowledge and practice on bio-medical waste management among the health care providers working in PHCs of Bagepalli Taluk with the view to prepare informational booklet. *International Journal of Medicine and Biomedical Research* 2 (1): 28 - 35.
- Narang, R. S., Manchanda, A., Singh, S., Verma, N. and Padda, S. 2012. Awareness of biomedical waste management among dental professionals and auxiliary staff in Amritsar, India. *Oral health and dental management* 11 (4): 162 - 169.
- Narendra, M., Kousar, H., Puttaiah, E. T. and Thirumala, S. 2013. Assessment of Biomedical waste of various hospitals in Mysore City Karnataka, India. *International Journal of Current Microbiology and Applied Sciences* 2 (3): 1 - 5.

- Nas, S. S. and Bayram, A. 2011. Environmental Problems from the Open Dump in Gümüşhane Province and Investigation of Biological Recycling for the Organic Solid Wastes. *Survival and Sustainability*: 1055 - 1063.
- NASA (National Aeronautics and Space Administration). 2012. NASA Sends Centaur Stage to Watery Grave. *Orbital Debris: Quarterly News* 16 (4): 1 – 12.
- Ndiaye, M., El Metghari, L., Soumah, M. M. and Sow, M. L. 2012. Biomedical waste management in five hospitals in Dakar, Senegal. *Bulletin de la Societe de pathologie exotique* **105** (4): 296 – 304.
- Nema, A., Pathak, A., Bajaj, P., Singh, H. and Kumar, S. 2011. A Case Study: Biomedical Waste Management Practices at City Hospital in Himachal Pradesh. *Waste Management & Research* **29** (6): 669 - 673.
- Nemathaga, F., Maringa, S. and Chimuka, L. 2008. Hospital solid waste management practices in Limpopo Province, South Africa: A case study of two hospitals. *Waste Management* **28**: 1236 - 1245.
- Obana, K., Fujie, G., Takahashi, T., Yamamoto, Y., Nakamura, Y., Kodaira, S., Takahashi, N., Kaneda, Y. and Shinohara, M. 2012: Normal-faulting earthquakes beneath the outer slope of the Japan Trench after the 2011 Tohoku earthquake: Implications for the stress regime in the incoming Pacific plate, *Geophysical Research Letters* **39** (7): L00G24, DOI: 10.1029/2011GL050399.
- Oelofse, S. H. and Nahman, A. 2013. Estimating the magnitude of food waste generated in South Africa. *Waste Management & Research* **31** (1): 80 - 86.
- Offenhuber, D., Wolf, M. I. and Ratti, C. 2013. Trash track – active location sensing for evaluating e-waste transportation. *Waste Management & Research* **31** (2) 150 - 159.
- Ogbonna, D. N. 2011. Characteristics and waste management practices of medical wastes in healthcare institutions in Port Harcourt, Nigeria. *Journal of Soil Science and Environmental Management* **2** (5): 132 - 141.
- Ogbonna, D. N., Chindah, A. and Ubani, N. 2012. Waste management options for health care wastes in Nigeria: A case study of Port Harcourt hospitals. *Journal of Public Health and Epidemiology* **4** (6): 156 - 169.
- Ohtsu, Y., Onoda, K., Kawashita, H. and Urasaki, H. 2011. A Comparison of Microwave Irradiation, Electric, and Hybrid Heating for Medical Plastic-waste Treatment. *Journal of Renewable and Sustainable Energy* **3**: 033106.
- Ojha, K. 2011. Status of MSW Management System in Northern India-an Overview. *Environment, Development and Sustainability* **13** (1): 203 - 215.

- Omar, D., Nazli, S. N. and Karuppannan, S. A. 2012. Clinical Waste Management in District Hospitals of Tumpat, Batu Pahat and Taiping. *Procedia-Social and Behavioural Sciences* **68**: 134 - 145.
- Ongondo, F. O., Williams, I. D. and Cherrett, T. J. 2011. How Are WEEE Doing? A Global Review of the Management of Electrical and Electronic Wastes. *Waste Management* **31** (4): 714 - 730.
- Özkan, A. 2013. Evaluation of healthcare waste treatment/disposal alternatives by using multi-criteria decision-making techniques. *Waste Management & Research* **31** (2): 141 - 149.
- Palwankar, P. V. and Singh, A. 2012. Safety And Measures For Auxiliary Staff Associated With Hospital Waste Disposal. *Indian Journal of Dental Sciences* **4**: 104 - 106.
- Pant, D., Joshi, D., Upreti, M. K. and Kotnala, R. K. 2012. Chemical and Biological Extraction of Metals Present in E Waste: A Hybrid Technology. *Waste Management* **32** (5): 979 - 90.
- Parthan, S. R., Milke, M. W., Wilson, D. C. and Cocks, J. H. 2011. Cost Function Analysis for Solid Waste Management: a Developing Country Experience. *Waste Management & Research* **30** (5): 485 - 491.
- Pasupathi, P., Sindhu, S., Ponnusha, B. S. and Ambika, A. 2011. Biomedical Waste Management for Health Care Industry: A Review. *International Journal of Biological & Medical Research* **2** (2): 472 - 486.
- Patel, S., Tiwari, R. R., Murarka S. and Kumar, S. 2011. Knowledge and attitude regarding mercury handling and disposal in students. *Waste Management & Research* **29** (7): 710 - 713.
- Patwary, M. A. and Sarker, M. H. 2012. Quantitative assessment of mortuary waste: occupational safety and environmental health. *Journal of Hospital Administration* **1** (1): 49 – 60.
- Patwary, M. A., O'Hare, W. T. and Sarker, M. H. 2011a. An illicit economy: Scavenging and recycling of medical waste. *Journal of Environmental Management* **92**: 2900 - 2906.
- Patwary, M. A., O'Hare, W. T. and Sarker, M. H. 2011b. Assessment of occupational and environmental safety associated with medical waste disposal in developing countries: A qualitative approach. *Safety Science* **49**: 1200 - 1207.
- Patwary, M.A., O'Hare, W. T. and Sarker, M. H. 2012. Occupational accident: An example of fatalistic beliefs among medical waste workers in Bangladesh. *Safety Science* **50** (1): 76 - 82.
- Perry, J., Jagger, J., Parker, G., Phillips, E. K. and Gomaa, A. 2012. Disposal of Sharps Medical Waste in the United States: Impact of Recommendations and Regulations, 1987-2007. *American Journal of Infection Control* **40** (4): 354 - 358.
- Peterson, P. J. and Granados, A. J. 1999. Hazardous waste indicators for national decision-makers. *Journal of Environmental Management* **55**: 249 – 263.

- Pfister, J. R., Archer, J. R., Hersil, S., Boers, T., Reed, K. D., Meece, J. K. Anderson, J. L. et al. 2011. Non-rural Point Source Blastomycosis Outbreak near a Yard Waste Collection Site. *Clinical Medicine & Research* **9** (2): 57 - 65.
- Pierce, J. S., Lacey, S. E., Lippert, J. F., Lopez, R. and Franke, J. E. 2013. Laser-Generated Air Contaminants from Medical Laser Applications: A State-of-the-Science Review of Exposure Characterization, Health Effects, and Control. *Journal of Occupational and Environmental Hygiene* **8** (7): 447 - 466.
- Polan, M. A. A., Al Noman, N., Jan, C. M., Hasan, M. R. and Saito, T. 2013. Practice and Knowledge of Health Personnel on Impact of Medical Wastes in Upazilla Health Complexes under Dhaka Division in Bangladesh. *City Dental College Journal* **10** (1): 1 - 4.
- Popov, V. E., Bratsev, A. N., Kuznetsov, V. A., Shtengel, S. V. and Ufimtsev, A. A. 2011. Plasma gasification of waste as a method of energy saving. *Journal of Physics* **275**: 1 – 9.
- Radha, R. 2012. Assessment of Existing Knowledge, Attitude, and Practices Regarding Biomedical Waste Management among the Health Care Workers in a Tertiary Care Rural Hospital. *International Journal of Health Sciences & Research* **2** (7): 14 – 19.
- Ragazzi, M., Tirler, W., Angelucci, G., Zardi, D. and Rada, E. C. 2013. Management of atmospheric pollutants from waste incineration processes: the case of Bozen. *Waste Management & Research* **31** (3): 235 - 240.
- Ratkovic, B., Andrejic, M. and Vidovic, M. 2012. Measuring the efficiency of a healthcare waste management system in Serbia with data envelopment analysis. *Waste Management & Research* **30** (6): 635 - 638.
- Rebmann, T., Citarella, B., Alexander, S., Russell, B. and Volkman, J. C. 2011a. Personal protective equipment use and allocation in home health during disasters. *American Journal of Infection Control* **39** (10): 823 - 831.
- Rebmann, T., Citarella, B., Subramaniam, D.P. and Subramaniam, B. S. 2011b. Assessing the infection prevention components of home health emergency management plans. *American Journal of Infection Control* **39** (10): 849 - 857.
- Richter, B. 2012. Opinion on Worldwide health effects of the Fukushima Daiichi nuclear accident. by J. E. Ten Hoeve and M. Z. Jacobson. *Energy & Environmental Science* **5** (9): 8758 - 8759.
- Rogers, D. E. C. and Brent, A. C. 2006. Small-scale medical waste incinerators – experiences and trials in South Africa. *Waste Management* **26**: 1229 - 1236.
- Rogers, D. E. C., Molefe, S., Gcwensa, Q., Van Den Bergh C., Kristiansen, T. and Otto, J. B. 2006. Report on Projections for Health Care Risk Waste Generation. National Waste Management Strategy Implementation Project, Department of Environmental Affairs and Tourism, South Africa.

- Rotter, V. S., Chancerel, P. and Schill, W. P. 2011. Practicalities of Individual Producer Responsibility under the WEEE Directive: Experiences in Germany. *Waste Management & Research* **29** (9): 931 - 944.
- Rudraswamy, S., Sampath, N. and Doggalli, N. 2012. Staff's attitude regarding hospital waste management in the dental college hospitals of Bangalore city, India. *Indian Journal of Occupational and Environmental Medicine* **16** (2): 75.
- Sagripanti, J. L., Hülseweh, B., Grote, G., Voß, L., Böhling, K. and Marschall, H. J. 2011. Diagnostics of Infectious Samples Microbial Inactivation for Safe and Rapid Diagnostics of Infectious Samples. *Applied Environmental Microbiology*: **77** (20): 7289.
- Sakai, S., Yoshida, H., Hirai, Y., Asari, M., Takigami, H., Takahashi, S., Tomoda, K., Peeler, M. V., Wejchert, J., Schmid-Unterseh, T., Douvan, A. R., Hathaway, R., Hylander, L. D., Fischer, C., Oh, G. J., Jinhui, L. and Chi, N. K. 2011. International Comparative Study of 3R and Waste Management Policy Developments. *Journal of Material Cycles and Waste Management* **13**: 86 - 102.
- Sari, S. Y. I., Ibrahim, K., Haroen, H., Afriandi, I., Sunjaya, D. K., Hinduan, Z. R., Antono, S. K., Susanto, H., Haryani, S., Pinxten, L. and Meheus, A. 2011. Knowledge, attitude and perceived adherence with universal precautions among health care workers in the obstetrics and gynaecology department of an Indonesian teaching hospital. *International Journal of Infection Control* **7**: i4.
- Sasu, S., Kümmerer, K. and Kranert, M. 2012. Assessment of Pharmaceutical Waste Management at Selected Hospitals and Homes in Ghana. *Waste Management & Research* **30** (6): 625 - 630.
- Sefouhi, L., Kalla, M. and Aouragh, L. 2011. Health Care Waste Management in the Hospital of Batna City (Algeria). International Conference on Environment and Bioscience IPCBEE Vol.21 IACSIT Press, Singapore.
- Seng, B., Kaneko, H., Hirayama, K. and Katayama-Hirayama, K. 2011. Municipal Solid Waste Management in Phnom Penh, Capital City of Cambodia. *Waste Management & Research* **29** (5): 491 - 500.
- Shalini, S., Harsh, M. and Mathur, B. P. 2012. Evaluation of Bio-medical Waste Management Practices in a Government Medical College and Hospital. *National Journal of Community Medicine* **3** (1): 80 – 84.
- Shanmugasundaram, J., Soulalay, V. and Chettiyappan, V. 2012. Geographic information system-based healthcare waste management planning for treatment site location and optimal transportation routeing. *Waste Management & Research* **30** (6): 587 - 595.
- Sharma, A., Sharma, V., Sharma, S. and Singh, P. 2013a. Awareness of biomedical waste management among health care personnel in Jaipur, India. *Oral Health and Dental Management* **12** (1): 32.

- Sharma, H. R., Abebe, T. Admassu, M., Teshaye, T., Aseffa, T. and Emana, M. 2011. Municipal Solid Waste Management and Community Awareness and Involvement in Management Practices: An Overview and a Case Study from Gondar Town of Ethiopia. *International Journal of Environment and Waste Management* **7** (3): 294 - 304.
- Sharma, H. R., Destaw, B., Negash, T., Negussie, L., Endris, Y., Meserte, G. and Ibrahime, A. 2013b. Municipal solid waste management in Dessie City, Ethiopia. *Management of Environmental Quality: An International Journal* **24** (2): 154 - 164.
- Shiferaw, Y., Abebe, T. and Mihret, A. 2012. Sharps injuries and exposure to blood and blood-stained body fluids involving medical waste handlers. *Waste Management & Research* **30** (12): 1299 - 1305.
- Siddiqui, F. Z., Zaidi, S., Pandey, S. and Khan, M. E. 2013. Review of past research and proposed action plan for landfill gas-to-energy applications in India. *Waste Management & Research* **31** (1): 3 - 22.
- Silindir, M. and Özer, A. Y. 2009. Sterilization methods and the comparison of E-Beam sterilization with gamma radiation sterilization. *Journal Pharmaceutical Sciences* **34**: 43 - 53.
- Singh, R. P., Singh, P., Araujo, A. S., Hakimi Ibrahim, M. and Sulaiman, O. 2011. Management of urban solid waste: Vermicomposting a sustainable option. *Resources, Conservation and Recycling* **55** (7): 719 - 729.
- Singh, A. and Jain, S. 2011. Prevention of Hepatitis B; Knowledge and Practices among Medical Students. *Healthline, Journal of Indian Association of Preventive and Social Medicine* **2** (2): 8 - 11.
- Singh, B. P., Khan, S. A., Agrawal, N., Siddharth, R. and Kumar, L. 2012. Current biomedical waste management practices and cross-infection control procedures of dentists in India. *International Dental Journal* **62** (3): 111 - 116.
- Smith, J. T., Willey, N. J. and Hancock, J. T. 2012. Low dose ionizing radiation produces too few reactive oxygen species to directly affect antioxidant concentrations in cells. *Biology Letters* **8** (4): 594 - 597.
- Srivastav, S., Kariwal, P., Singh, A. K. and Shrotriya, V. P. 2012. Evaluation of biomedical waste management practices in multi-speciality tertiary hospital. *Indian Journal of Community Health (IJCH)* **21**(1,2): 46 - 50.
- Stasiskiene, Z., Gaiziuniene, J. and Zidoniene, S. 2011. Assessing the Sustainability of the Lithuanian Hazardous Waste Management System. *Journal of Industrial Ecology* **15** (2): 268 - 283.
- Statistics South Africa. 2012. Population Statistics. Government Printer. Pretoria.

- Su, S., Wu, W., Gao, J., Lub, J. and Fan, C. 2012. Nanomaterials-based sensors for applications in environmental monitoring. *Journal of Materials Chemistry* **22**: 18101 - 18110.
- Sushma, M. K., Bhat, S., Shetty, S. R. and Babu, S. G. 2012. Biomedical Dental Waste Management and Awareness of Waste Management Policy among Private Dental Practitioners in Mangalore City, India. *Tanzania Dental Journal* **16** (2): 39 - 43.
- Syed, E. H., Mutahara, M. and Rahman, M. 2012. Medical Waste Management (MWM) in Dhaka, Bangladesh: It's a Review. *Home Health Care Management & Practice* **24** (3): 140 - 145.
- Taghipour, H., Norouz, P., Jafarabadi, M. A., Nazari, J., Hashemi, A. A., Mosaferi, M. and Dehghanzadeh, R. 2011. E-waste Management Challenges in Iran: Presenting Some Strategies for Improvement of Current Conditions. *Waste Management & Research* **30** (11): 1138 - 1144.
- Tan, Z. and Xiao, G., 2012. Leaching characteristics of fly ash from Chinese medical waste incineration. *Waste Management & Research* **30** (3): 285 - 294.
- Tanigawa, K., Hosoi, Y., Hirohashi, N., Iwasaki, Y. and Kamiya, K. 2012. Loss of life after evacuation: Lessons learned from the Fukushima accident. *Lancet* **379** (9819): 889 – 891.
- Tauseef, S. M., Premalatha, M., Abbasi, T. and Abbasi, S. A. 2013. Methane capture from livestock manure: Review. *Journal of Environmental Management* **117**: 187 - 207.
- Tirado-Soto, M. M. and Zamberlan, F. L. 2013. Networks of recyclable material waste-picker's cooperatives: An alternative for the solid waste management in the city of Rio de Janeiro. *Waste Management* **33**: 1004 - 1012.
- Titto, E. de, Savino, A. A. and Townend, W. K. 2012. Healthcare waste management: the current issues in developing countries. *Waste Management & Research* **30**(6): 559 - 561.
- Trotter II, R.T. 2012. Qualitative research sample design and sample size: Resolving and unresolved issues and inferential imperatives. *Preventive Medicine* **55**: 398 - 400.
- Turner, T. F., Trexler, J. C., Harris, J. L. and Haynes, J. L. 2000. Nested cladistic analysis indicates population fragmentation shapes genetic diversity in a freshwater mussel. *Genetics* **154**: 777 – 785.
- Tsydenova, O. and Bengtsson, M. 2011. Chemical hazards associated with treatment of waste electrical and electronic equipment. *Waste Management* **31** (1): 45 - 58.
- Ullah, J. H. and Khan, M. A. 2011. Proposed Model for Healthcare Waste Management. *Pakistan Journal of Medical Sciences* **27** (4).
- Umar, A. and Yaro, A. 2011. Hospital Waste Management in Katsina State. *Bayero Journal of Pure and Applied Sciences* **2** (2): 22 - 26.

- Umar, A., Yaro, A. and Abdulkarim, B. 2011. Assessment of Healthcare Waste Generated by Some Selected Public Hospitals in Katsina State, Nigeria. *Bayero Journal of Pure and Applied Sciences* **2** (2): 13 -15.
- van Duijn, H. J., Belo, J. N. Blom, J. W., Velberg, I. D. and Assendelft, W. J. J. 2011. Revised Guidelines for Cardiovascular Risk Management Time to Stop Medication? A Practice-based Intervention Study. *British Journal of General Practice* **61** (587): e347 - e352.
- Vilavert, L., Nadal, M., Schuhmacher M. and Domingo, J. L. 2012. Long-term monitoring of dioxins and furans near a municipal solid waste incinerator: human health risks. *Waste Management & Research* **30** (9): 908 - 916.
- Voudrias, E., Goudakou, L., Marianthi, K. and Softa, A. 2012. Composition and production rate of pharmaceutical and chemical waste from Xanthi General Hospital in Greece. *Waste Management* **32**: 1442 - 1452.
- Wahab, A. B. and Adesanya, D. A., 2011. Medical Waste Generation in Hospitals and Associated Factors in Ibadan Metropolis, Nigeria. *Research Journal of Applied Sciences, Engineering and Technology* **3** (8): 746 - 751.
- Wang, X. and Geng, Y. 2012. Municipal solid waste management in Dalian: practices and challenges. *Frontiers of Environmental Science & Engineering* **6** (4): 540 - 548.
- Watanabe, T., Tsuchiya, N., Oura, Y., Ebihara, M., Inoue, C., Hiramoto, N., Yamada, R., Yamasaki, S., Okamoto, A., Nara, F.W. and Nunohara, K. 2012. Distribution of artificial radionuclides (^{110m}Ag , ^{129m}Te , ^{134}Cs , ^{137}Cs) in surface soils from Miyagi Prefecture, northeast Japan, following the 2011 Fukushima Dai-ichi nuclear power plant accident. *Geochemical Journal* **46**: 279 - 285.
- Wath, S. B., Dutt, P. S. and Chakrabarti, T. 2011. E-waste Scenario in India, Its Management and Implications. *Environmental Monitoring and Assessment* **172** (1): 249 - 262.
- Weber, R., Watson, A., Forter, M. and Oliaei, F. 2011. Review Article: Persistent Organic Pollutants and Landfills - a Review of Past Experiences and Future Challenges. *Waste Management & Research* **29** (1): 107 - 121.
- WHO (World Health Organisation). 1998. Recommendations and Proposed Priority Activities for Disposal and Destruction. 6th Technet Consultation. Copenhagen. Denmark.
- WHO (World Health Organisation). 2011a. Waste from health-care activities. Fact sheet No: 253. Switzerland.
- WHO (World Health Organisation). 2011b. Health-care waste management: To reduce the burden of disease, health-care waste needs sound management, including alternatives to incineration. Fact sheet No: 281. Switzerland.

- Xue, M., Li, J. and Xu, Z. 2013. Management strategies on the industrialization road of state-of-the-art technologies for e-waste a review: the case study of electrostatic separation. *Waste Management & Research* **31** (2): 130 - 140.
- Yan, M., Li, X., Yang, J., Chen, T., Lu, S., Buekens, A.G., Olie, K. and Yan, J. 2012. Sludge as dioxins suppressant in hospital waste incineration. *Waste Management* **32** (7): 1453 – 1458.
- Zaman, A. U. and Lehmann, S. 2013. The Zero Waste Index: A Performance Measurement Tool for Waste Management Systems in a 'Zero Waste City'. *Journal of Cleaner Production* xxx 1 - 10. DOI: 10.1016/j.jclepro.2012.11.041.
- Zhang, X., Mao, Y., Jiang, H., Gong, X., Zheng, J. and Lu, G. 2011b. Experimental Teaching of New Drug Research and Evaluation in Compliance with Good Laboratory Practice. *Research and Exploration in Laboratory* **6**: 087.
- Zhang, Y., Li, Q., Meng, A. and Chen, C. 2011a. Carbon Monoxide Formation and Emissions during Waste Incineration in a Grate-circulating Fluidized Bed Incinerator. *Waste Management and Research* **29** (3): 294 - 308.
- Zhang, C., Qiao, Q., Appel, E. and Huang, B. 2012. Discriminating sources of anthropogenic heavy metals in urban street dusts using magnetic and chemical methods. *Journal of Geochemical Exploration* **119-120**: 60 - 75.

Appendix A (Interview)

Section A: General Information:

1. Health setting:

- | | |
|------------------------|--------------------------|
| 1. Regional Hospital | ☐ |
| 2. District Hospital | ☐ |
| 3. Laboratory | ☐ |
| 4. Dental Clinic | ☐ |
| 5. Dispensary | ☐ |
| 6. Veterinary Hospital | ☐ |
| 7. Other | ☐ |

2. a) Person interviewed:

- | | |
|--------------------------|--------------------------|
| A. Head of Hospital | ☐ |
| B. Doctor/Surgeon | ☐ |
| C. Head of department | ☐ |
| D. Supervisor | ☐ |
| E. Pharmacist | ☐ |
| F. Medical waste handler | ☐ |

b) Education:

- | | |
|----------------------|--------------------------|
| A. Post Graduate | ☐ |
| B. Graduate | ☐ |
| C. Senior Secondary | ☐ |
| D. Junior Secondary | ☐ |
| E. Primary Education | ☐ |
| F. Illiterate | ☐ |

3. a) Age

☐

b) Sex

☐

4. How much medical waste is generated every day in your health care setting?

.....

.....

Section B: Waste Management Policy:

1. Are you aware of any legislation applicable to the hospital (medical) waste management? Yes ☐ No ☐

If yes, please list the legislative Act

.....

.....

2. Does your health care setting have a waste management plan?

Yes ☐

No ☐

3. Are there waste management responsibilities included in the job description of hospital supervisory staff (Head of hospital, Departmental Heads, Nursing Superintendent, Nursing Staff, Laboratory Supervisor, Pharmacist)?

Yes ☐

No ☐

4. Are you aware of authorization?

Yes ☐

No ☐

If yes, when is it required?

.....

.....

Section C: Waste Management Practices:

5. Tick the facilities available for waste management

Segregation	Containment	Ordinary Burial	Deep burial	Burning	Autoclave	Incineration
☐	☐	☐	☐	☐	☐	☐

6. Should waste be segregated into different categories?

Yes ☐

No ☐

If yes, who does the segregation?

1. Head of Hospital ☐
2. Doctor / Surgeon ☐
3. Head of department ☐
4. Supervisor ☐
5. Pharmacist ☐
6. Medical waste handler ☐
7. Do not know ☐

7. Do you colour code the waste for disposal?

Yes ☐

No ☐

If yes, match the following

Yellow	Puncture proof plastic bag/ Container	Incinerator / Deep Burial
Red	Plastic Bag	Disposal Landfill
Blue/White	Plastic Bag	Autoclave/ Microwave
Black	Disinfected container/Plastic Bag	Autoclave/ Microwave

8. Is the infectious waste labeled with basic Bio-hazard symbol?

Yes ☐

No ☐

9. Where do you dispose medical waste?

1. Dumping in municipal bin ☐
2. Each department collects ☐
3. Any authorized waste collection ☐
4. Any means (specify) ☐

10. Do you maintain a register for waste disposal?

Yes ☐

No ☐

11. Has your healthcare setting done a waste audit in the last three years?

Yes ☐

No ☐

Section D: Employee education:

12. Have you undergone any training programme on medical waste management?

Yes ☐

No ☐

13. Does your hospital provide annual education on waste management its employees?

Yes ☐

No ☐

14. Would you like to attend a programme on medical waste management?

Yes ☐

No ☐

Section E: Attitude assessment:

15. Please tick whichever is applicable

a) Safe management of medical waste is not an issue at all

Agree ☐ Disagree ☐ No comment ☐

b) Safe management of medical waste is the responsibility of government

Agree ☐ Disagree ☐ No comment ☐

c) Waste management is team-work/ no single class of people is responsible for safe management

Agree ☐ Disagree ☐ No comment ☐

d) Safe management efforts by hospital increases financial burden on management

Agree ☐ Disagree ☐ No comment ☐

e) Safe management of medical waste is an extra burden on work

Agree ☐ Disagree ☐ No comment ☐

Thank you for your co-operation

Appendix B (Observation)

Item observed	Yes	No	Remarks (if any)
1. Are personnel dressed in protective wear?			
2. Is the department considered to be generating MW?			
3. Is medical waste collection point easily accessible?			
4. Are the various collectors easily noticeable?			
5. Are they colour-coded accordingly?			
6. Are there signs of mixed waste in the containers?			
7. Is MW transported by safely (i.e. by wheeled trolley)?			
8. Is there a central collection point for MW?			
9. Timeous removal of MW (i.e. < 24 hrs.) from this central point?			
10. Are there rodents/ pests/ noticeable odours at this point?			

*MW = medical waste

Appendix C (Letter of Introduction – HOD (FS – Health))



TO WHOM IT MAY CONCERN

From: Prof. TM Ruhiiga
Postgraduate Research Coordinator
Geography & Environmental Science
School of Environmental & Health Sciences
Faculty of Agriculture, Science & Technology
Mafikeng Campus
North West University
Private Bag X2046
Mmabatho 2735

Date: 8th May 2012

**Re: LETTER OF INTRODUCTION & REQUEST FOR ASSISTANCE: Mr. Mahasa, PS
(Student Number: 24009393)**

This is to inform you that Mr. Mahasa, P.S., currently a Lecturer in Geography at the University of the Free State (Qwa-Qwa Campus) is currently registered with us for a Research MSc degree in Environmental Science. His research deals with an assessment of medical waste management at medical facilities in the North Eastern Free State and the ultimate purpose is to develop a framework for improving the handling of medical waste. The department conducts at masters and doctoral degree level applied research targeting addressing practical problems facing public health, the environment, poverty and urbanisation. Where such research includes human and animal subjects, we adhere to research guidelines as per the MRC, of South Africa.

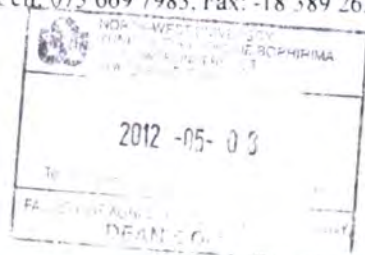
To this end, and on behalf of the Department of Geography & Environmental Science, I would like to appeal for your cooperation and assistance as part of his research involves the conduct of observations at various sites and the administration of a short interview to medical personnel. He needs an official authorisation before he can proceed with this type of research. Should there be any additional information required in this regard, please feel free to let me know. And, I will not hesitate to avail such information.

Thank you

A handwritten signature in black ink, appearing to read 'TM Ruhiiga'.

TM Ruhiiga

Tel: -18 389 2310; Cell: 073 669 7983; Fax: -18 389 2637



8200 Namibia Square
BLOEMFONTEIN 9323
09 May 2012

The Head of Health
Dept of Health, Bophelo House
P/Bag X227
BLOEMFONTEIN 9300

**Re: Request to perform research on various sites in the North Eastern Free State Health
Facilities**

Dear Sir/Madam,

I am a student at the North West University (NWU), currently pursuing a study towards a Masters degree in Environmental Sciences. I am expected to undertake a research project as part of my degree.

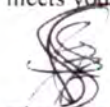
The purpose of my research is to assess medical waste management practices in several hospitals in the North-eastern Free State, so as to investigate establishing the kind of intervention that could be needed to address shortcomings, if any.

I want to conduct interviews with some medical personnel; the session will be about half an hour long. The research will be done under strict adherence to the MRC (South Africa) and NWU Guidelines for research.

Their participation in this study is voluntary, are under no obligation to participate and have the right to withdraw at any time. They can also feel free to make any inquiries regarding the study at any point during or after interview.

The proposed sites are: Mofumahadi Mmanapo Mopeli Regional Hospital, Elizabeth Ross District Hospital, Medi-Clinic (Hoogland), Dihlabeng Regional Hospital, Phekolong Hospital, Corona Sub Acute Hospitals, Thebe Hospital, Mantsopa Hospital, Nketoana Hospital and Phumelela Hospital.

Thank you in advance for allowing me to undertake this study in the hope that my application meets your favourable consideration.



PS Mahasa
Cell: 0765699062
E-mail: mahasaps@qwa.ufs.ac.za

CONSENT LETTER FOR PARTICIPATION

Dear Sir/Madam,

I am a student at the North West University (NWU), currently pursuing a study towards a Masters degree in Environmental Sciences. I am expected to undertake a research project as part of my degree.

The purpose of my research is to assess medical waste management practices in several hospitals in the North-eastern Free State, so as to investigate establishing the kind of intervention that could be needed to address shortcomings, if any.

I want to conduct interview with you; the session will be about half an hour long. The research will be done under strict adherence to the MRC (South Africa) and NWU Guidelines for research.

Your participation in this study is voluntary; you are under no obligation to participate and you have the right to withdraw at any time. Feel free to make any inquiries regarding the study at any point during or after interview.

Thank you so much for taking part in this study.

PS Mahasa

Researcher

Cell: 0765699062

E-mail: mahasaps@qwa.ufs.ac.za

This consent form has been read and explained to me and I voluntarily consent to participate in this study.

Participant's signature

Date _____

Researcher's signature

Date _____

Appendix F (Content of Hazardous Medical Waste Survey Interviews)

Component	Contents
Medical facility information	• Facility name, location, and type • Number of sections/ wards • Number of beds • Number of in-patients and out-patients • Number of medical staff
Waste generation and segregation	• Quantity of hazardous waste generated • Segregation methods • Types of bags and containers used • Appropriate use of colour coded containers and bags
Waste collection and storage	• Waste tracking records • Waste handling procedure/ instruction • Frequency of waste collection • Availability of central storage area and whether dedicated to hazardous waste only • Waste storage location, condition, security and cleanliness • Frequency of cleaning the storage area
Waste transport	• Availability of dedicated trolleys for on-site hazardous waste transport • Type of off-site waste transport for hazardous waste • Availability of dedicated vehicles for hazardous waste • Off-site transport responsibility • Transport vehicles condition and registration
Waste treatment and disposal General waste management issues	• Treatment and disposal methods for hazardous HCW types at the surveyed facilities • Healthcare waste management, including: responsibilities, procedures, training, supervision, facility audit and inspection • North eastern Free State regulatory requirements and their practices

Appendix G Geography by Population group and Sex

Space-Time Research Census 2001 (October 2001 boundaries) Table 1 Geography by Population group and Sex for Person weighted											
	Black African		Coloured		Indian or Asian		White		Total		
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
Free State	1140329	1240743	40856	42337	2064	1654	114355	124436	1297605	1409170	
DC16: Xhariep District Municipality	49694	51245	10757	11136	29	26	6041	6320	66521	68727	
FS161: Letsemeng	13774	14155	5252	5604	10	13	2042	21078	21078	21904	
FS162: Kopanong	19377	21192	4863	5109	13	10	2604	2776	26857	29088	
FS163: Mookare	16544	15899	641	423	5	-	1395	1412	18585	17736	
DC17: Mookare District Municipality	288997	319118	17227	18104	735	606	39379	44096	346337	381924	
FS171: Naledi	11848	12936	484	451	52	42	843	823	13226	14252	
FS172: Mangaung	254286	280167	15509	16414	574	441	36629	41419	306999	338442	
FS173: Mantsopa	22863	26015	1233	1239	109	122	1907	1853	26112	29230	
DC18: Lejweleputswa District Municipality	287466	299180	6502	6687	307	229	27375	29267	321649	335363	
FS181: Maseru	30123	29129	441	380	13	7	2011	2307	32587	31822	
FS182: Tokologo	13382	13941	1086	1091	7	-	1438	1508	15913	16543	
FS183: Tswelopele	24546	26361	368	349	7	11	947	1125	25868	27845	
FS184: Matjhabeng	175012	181086	4319	4585	270	205	20770	21924	200370	207800	
FS185: Nala	44402	48663	288	282	11	4	2209	2404	46911	51353	
DC19: Thabo Mofutsanyane District Municipality	319761	371080	1771	1834	709	578	14487	15719	336728	389211	
FS191: Setsoto	53093	61882	535	568	335	311	3078	3393	57041	66154	
FS192: Dithabeng	53468	61155	890	950	114	72	5903	6377	60375	68555	
FS193: Nketoana	27271	30947	75	66	22	11	1699	1859	29067	32884	
FS194: Maluti a Phofung	163456	191970	214	205	227	172	2215	2328	166111	194676	
FS195: Phumelela	22403	25033	56	45	13	11	1588	1759	24059	26847	
FSDMA19: Golden Gate Highlands National Park	70	93	-	-	-	-	5	3	75	96	
DC20: Northern Free State District Municipality	194411	200120	4601	4575	285	215	27073	29034	226370	233946	
FS201: Mookgata	72525	72267	2330	2363	113	94	8655	9544	83623	84269	
FS203: Ngwathe	48721	53545	1741	1892	46	28	6011	6825	56520	62290	
FS204: Metsimaholo	48201	45803	378	204	102	83	10565	10641	59246	56731	
FS205: Mafube	24964	28505	152	117	24	10	1842	2024	26981	30656	

Created on Monday, March 12, 2012
Space-Time Research Web page: www.spacetime-research.com
Space-Time Research Online support: support@spacetime-research.com
SuperCROSS. Copyright © 1993-2012 Space Time Research Pty Ltd. All rights reserved.

(Source: Statistics South Africa, March 12, 2012)

Appendix H Geography by Attending school (Institution)

**Space-Time Research
Census 2001 (October 2001 boundaries)
Table 1
Geography by Attending school (institution)
for Person weighted**

	None	Pre-school	School	College	Technikon	University	Adult education centre	Other	Total
Free State	1799906	59886	793266	15588	9910	17307	7765	3147	2706775
DC16: Xhariep District Municipality	95192	3010	36060	153	115	183	457	77	135248
FS161: Letsemeng	31554	920	10195	44	31	66	143	30	42982
FS162: Kopanong	38642	1457	15475	70	46	69	158	27	55944
FS163: Mokokare	24996	633	10390	39	38	48	155	20	36321
DC17: Mthetho District Municipality	481413	17082	203261	6763	6835	9486	2343	1079	728261
FS171: Naledi	17179	623	9418	52	26	78	82	21	27479
FS172: Mangaung	427279	15274	177142	6611	6737	9250	2161	986	645440
FS173: Mantsopa	36955	1185	16700	100	71	158	100	72	55342
DC18: Lejweletswa District Mu	453407	13684	180217	3243	958	2953	1876	675	657012
FS181: Masilonyana	44457	1113	18299	141	58	93	216	31	64409
FS182: Tokologo	23286	652	8321	36	21	63	61	16	32455
FS183: Tswelopele	36838	694	15906	56	16	70	93	41	53714
FS184: Matjhabeng	281640	9706	108641	2896	816	2599	1332	540	408170
FS185: Nala	67187	1520	29049	114	46	128	174	46	98264
DC19: Thabo Mofutsanyane Distr	456914	14299	244712	3334	954	3243	1808	674	725939
FS191: Setsoto	81463	2316	38461	216	96	254	329	60	123194
FS192: Dihlabeng	87324	2698	37466	567	143	445	187	100	128929
FS193: Nketoana	39288	1175	21132	85	37	100	107	26	61951
FS194: Maluti a Phofung	215708	6925	131203	2392	655	2380	1083	441	360787
FS195: Phumelela	33015	1181	16403	74	19	65	102	47	50906
FSDMA19: Golden Gate Highl.	115	4	48	-	4	-	-	171	171
DC20: Northern Free State Distric	312978	11812	129016	2095	1049	1441	1281	642	460316
FS201: Mookha	117011	3983	44377	850	278	508	480	404	167892
FS203: Ngwathe	80325	3400	34308	186	117	227	193	53	118810
FS204: Metsimaholo	79881	2884	30441	987	618	610	410	147	115977
FS205: Mafube	35761	1545	19890	72	37	96	198	38	57637

Created on Monday, March 12, 2012

Space-Time Research Web page: www.spacetime-research.com

Space-Time Research Online support: support@spacetime-research.com

SuperCROSS. Copyright © 1993-2012 Space Time Research Pty Ltd. All rights reserved.

(Source: Statistics South Africa, March 12, 2012)

Appendix I Geography by Language

Space-Time Research Census 2001 (October 2001 boundaries) Table 1 Geography by Language for Person weighted													
	Afrikaans	English	IsiNdebele	IsiXhosa	IsiZulu	Sepedi	Sesotho	Setswana	SiSwati	Tshivenda	Xisonga	Other	Total
Free State	323082	31246	10000	246192	138091	7007	1742939	185389	7451	1433	8960	4985	2706775
DC16: Xhariep District Municipality	50162	861	70	26852	342	135	50146	6244	161	28	157	90	135248
FS161: Letsemeng	28256	289	6	4597	94	54	5425	4133	27	-	27	72	42982
FS162: Kopanong	18138	360	50	12690	82	73	22433	1891	94	20	98	13	55944
FS163: Mookgare	3767	212	13	9565	166	7	22288	220	40	5	32	5	36321
DC17: Mookgare District Municipality	111590	12854	2853	80142	4877	1458	389939	120668	1471	219	838	1351	728261
FS171: Naledi	2327	253	40	1819	52	6	22753	152	30	5	16	25	27479
FS172: Mangaung	104165	11509	2717	77588	4700	1403	319875	120086	1255	212	766	1163	645440
FS173: Mantsopa	5098	1092	96	734	125	49	47311	430	186	-	56	163	55342
DC18: Lejweletswa District Municipality	66423	7983	4284	99459	11056	1673	403868	50838	2368	553	6364	2145	657012
FS181: Maseru	5145	221	162	8134	275	127	43226	5778	292	23	825	200	64409
FS182: Tlokologo	6237	169	166	3733	123	64	2584	19290	45	16	21	8	32455
FS183: Tswelopele	2714	84	616	12481	236	84	27299	10024	120	13	16	26	53714
FS184: Matjhabeng	47053	7335	1663	63775	8578	1188	259349	10014	1648	477	5231	1859	408170
FS185: Nala	5274	174	1676	11336	1845	209	71410	5731	262	24	271	53	98264
DC19: Thabo Mofutsanyane District Municipality	32480	4800	1548	4852	90588	1112	586022	1518	1909	110	358	642	725939
FS191: Setsoto	6742	1500	667	802	666	113	111971	289	238	29	36	140	123194
FS192: Dikhabeng	13338	1507	225	781	8896	198	103115	249	383	33	101	105	128929
FS193: Nketoana	3733	185	68	587	9838	96	47229	88	92	10	18	6	61951
FS194: Maluti a Phofung	5208	1420	561	2378	44395	633	303674	840	1074	34	193	378	360787
FS195: Phumelela	3446	188	27	300	26787	73	19885	52	123	4	9	13	50906
FSDMA19: Golden Gate Highlands National Park	12	-	-	4	7	-	147	-	-	-	-	-	171
DC20: Northern Free State District Municipality	62428	4748	1245	34888	31227	2629	312964	6120	1543	523	1244	758	460316
FS201: Mophaka	22180	1276	646	11167	3322	316	124043	3270	705	55	503	410	167892
FS203: Ngwathe	16069	722	354	12150	6379	198	80626	1676	300	49	202	85	118810
FS204: Metsimaholo	20082	2584	208	10242	8269	1990	69887	1121	440	410	510	234	115977
FS205: Mafube	4097	166	37	1328	13257	125	38409	54	98	9	29	28	57637

Created on Monday, March 12, 2012
Space-Time Research Web page: www.spacetimeresearch.com
Space-Time Research Online support: support@spacetimerearch.com
SuperCROSS: Copyright © 1993-2012 Space Time Research Pty Ltd. All rights reserved.

Created on Monday, March 12, 2012

Space-Time Research Web page: www.spacetime-research.com

Space-Time Research Online support: support@spacetime-research.com

SuperCROSS. Copyright © 1993-2012 Space Time Research Pty Ltd. All rights reserved.

(Source: Statistics South Africa, March 12, 2012)