The Identification of Environmentally Sound Technologies for Healthcare Waste Management in Lesotho

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ABSTRACT

Waste resulting from healthcare activities is hazardous due to its potential risk of infection to healthcare workers, waste workers and the public. Many tools and approaches have been applied in waste management in developed countries, but are not suitable for application in developing countries due to their complexity and extensive data and resource requirements. WasteOpt was therefore developed and applied as an appropriate decision-making tool in the developing country context. WasteOpt comprises of the Analytical Hierarchy Process (AHP), costing and Life cycle management (LCM).

The purpose of this study was to identify environmentally sound technologies (ESTs) that minimise the risk of infection by healthcare waste (HCW) in rural clinics. Rural clinics were selected because apart from financial constraints, they are challenged by the lack of procedure, infrastructure and technologies to develop reasonable waste management plans that can be implemented within a practicable time frame. WasteOpt was applied to aid in identifying ESTs in relation to the infection risks and costs of the technologies.

Experts in waste management in Lesotho were involved in a workshop for the ranking of technologies. The overall weighting values of the rankings were converted to risk factors for individual options and for alternatives (combination of options). Risk factors were classified as low, medium and high risk. The technologies within a single class were differentiated by analysing the cost of acquiring and running the technology to qualify as ESTs. The ESTs identified for Lesotho are Engineered containers, Refrigerated engineered facility, engineered wheeled transport, detailed procedures, multi chamber incinerator, engineered pit and landfill.

Ten (10) clinics in Lesotho were also assessed as case studies using the WHO RAT. The RAT was first modified to include questions on financial management at the clinics. The calculated risk factors were applied to the case studies to assess the risk under which healthcare workers operate in those clinics. The additive minimum risk for the overall life cycle of waste was 4.0 (excluding central treatment and disposal). The clinic workers were found to be at a risk of between 1.1×10^{-4} and 7.8×10^{-5}, which proves that rural clinics in Lesotho are still using inappropriate technologies.

In terms of financing for waste management, public clinics were found to have little decision-making powers over funds and had less accountability measures. CHAL clinics which are managed by churches in Lesotho had more control of funds and exhibit more accountability. All clinics had no targets for saving funds from waste management activities.

WasteOpt can be applied as a decision-making tool for HCW in Lesotho since it overcomes the barriers that inhibit environmentally sound management of HCW in developing countries.

In conclusion: WasteOpt can be applied as a decision-making tool for different types of waste by replacing HCW options with respective ones and designing a relevant questionnaire for qualitative data capture. WasteOpt can then be applied in a developing country to aid sustainable waste management decision-making. Informed decision-making helps resource poor managers to select cost-effective but low-risk options, which will be sustainable in the future.

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LIST OF ACRONYMS

AHP:	Analytical Hierarchy Process
CBA:	Cost-Benefit Analysis
CBO:	Community Based Organization
CEDAMA:	Committee for Environmental Data Management Authority
CHAL:	Christian Health Association of Lesotho
CHEMAC:	Chemical Management Committee
COWMAN:	Committee on Waste Management
EIA:	Environmental Impact Assessment
EST:	Environmentally Sound Technology
HCW:	HealthCare Waste
HCWM:	HealthCare Waste Management
ISWM:	Integrated Solid Waste Management
LCM:	Life Cycle Management
LEA:	Lesotho Environment Authority
MoHSW:	Ministry of Health and Social Welfare
MoLE:	Ministry of Labour and Employment
MoLG:	Ministry of Local Government
MoNR:	Ministry of Natural Resources
MoTEC:	Ministry of Tourism, Environment and Culture
NES:	National Environment Secretariat
NGO:	Non-Governmental Organisation
NPO:	Non Profit Organisation
PHC:	Primary Health Care
RAT:	Rapid Assessment Tool
SADC:	Southern African Development countries
WHO:	World Health Organization
WCED:	World Convention on Environment and Development
WM:	Waste Management

LIST OF TECHNICAL ABBREVIATIONS

CD: Controlled dump
DP: Detailed procedures
EC: Engineered container
EC>EC: Aggregating from engineered container to engineered container
EC>nEC: Aggregating from engineered container to non-engineered container
EL: Engineered location
EP: Engineered pit
EnW: Engineered non-wheeled transport
EWT: Engineered wheeled transport
EWV: Engineered wheeled vehicle
GT: General transport
GV: General vehicle
IT: Inappropriate transport
IV: Inappropriate vehicle
LF: Landfill
MCI: Multi-chamber incinerator
nREF: Non-refrigerated engineered facility
nP: No procedures
nRnEF: Non-refrigerated non-engineered facility
OAB: Open air burning
OD: Open dump
REF: Refrigerated engineered facility
SASSI-E: South African small-scale incinerator-engineered
SASSI-M: South African small-scale incinerator-minimum requirements
SCI: Single chamber incinerator

DEFINITION OF KEYWORDS

Analytical Hierarchy Process: A multi-attribute decision support process based on organizational hierarchies and weighting of attributes/options.

Appropriate technology: A good match between technology utilized and the resources required for its optimal use. It ranges from low, medium to high technology (Khalil, 2000).

Best Practicable Environmental Option: An option that provides most benefits and least damage (long and short term) to the environment at an acceptable cost (Royal society of Chemistry, 1995).

Environmentally Sound Technology: A technology that protects the environment. It is less polluting, uses all resources in a more sustainable manner than the technology for which it is a substitute (Agenda 21, Chapter 34).

Healthcare waste: All waste generated within a healthcare establishment. Seventy five percent (75 %) of this waste is typically defined Healthcare General Waste, while the remainder is Healthcare Risk waste.

Primary Health Care facility: facilities at and from which a range of Primary Health Care services are provided, but no facilities exist to admit a patient to inpatient services. It is normally open only 8 hours a day. Certain staff may, however, be required to sleep at or near the clinic so that they are available on call in case of emergency.

Rural Area: an area with lower service quality that urban areas, whose population is poor and uneducated and agriculture being the principal land use (Lassey, 1977).

Sustainable waste management: integrated management of all types of wastes across all media and time in a way that is economically, environmentally and socially sustainable for present and future generations.

System: An entity of interacting elements that function individually or in unison to achieve the objectives of the entity as a whole (Chacko, 1989).

Systems analysis: A study of procedures for collection and evaluation of data of a system to determine ways of improving the functionality of the system (Checkland, 1989)

Systems approach: A way of thinking of total systems so as to constitute a planned and organised approach to problem solving (Wilson, 1974)

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CHAPTER 1

General background

1.1 INTRODUCTION

As third world countries evolve into more industrialised economies, rapid urbanisation results in more development in urban rather than in rural areas. These rural communities are usually isolated and the isolation is reflected in their lack of access to services (Jazairy *et al.,* 1992). One such service, health care provision, is faced with managing health care waste (HCW), despite its lack of resources and procedures.

Safe management of HCW will not only reduce the uncertainty and risk associated with poor practices in public health, but also improve the value of the environment (Asante-Duah, 1993). As English *et al.* (1999) argue, it is vital that environmental decision-makers apply appropriate decision-making tools to overcome difficulties in setting priorities as the result of uncertainties of impacts resulting from changes to environmental and public health systems, as well as uncertainties in budget/costs. The use of appropriate tools can also ensure that problems arising from the mismanagement of HCW are systematically analysed and subsequently solved, even with limited budgets. It is the general aim of this research to identify technologies and best practices in HCWM that are environmentally sound, by the application of a specially developed tool.

1.2 HCWM TRENDS IN DEVELOPED AND DEVELOPING COUNTRIES

1.2.1 HealthCare Waste Management (HCWM) in Developed Countries

Proper HCWM, ideally, is integrated and is based on the hierarchical approach illustrated in Figure 1.1.

<table>
<tr><td>Avoidance</td><td rowspan="3">Cleaner production</td></tr>
<tr><td>Minimisation</td></tr>
<tr><td>Recycling</td></tr>
<tr><td colspan="2">Treatment</td></tr>
<tr><td colspan="2">Disposal</td></tr>
</table>

Figure 1.1: The hierarchy of waste management

The figure shows that the first hierarchical steps can be clustered into the cleaner production concept, which is well established in developed countries. Cleaner production mostly entails waste reduction and material recovery (UNEP IETC, 1996). In developed countries, waste management is governed by legislation, which was based on end-of-pipe regulations and strategic targets. After a realisation that end-of-pipe regulations do not bring about major positive changes, focus has been redirected to strategic targets, which define ways of managing waste in the future (McDougall *et al.,* 2001).

Waste management systems in developed countries are characterised by an ever-increasing use of sophisticated technologies due to the availability of capital for major investments (Friend, 2001). With low unemployment rates typically between 5% and 9.9% (ILO, 2004) and high per capita incomes averaging US$32,040 (World Bank, 2004), the public can afford the externalities of healthcare, which include cleaner waste production.

1.2.2 HCWM in Underdeveloped Countries (The Case of Lesotho)

The nature of problems experienced by developed countries differs significantly from those of developing countries (Palmer Development Group, 1996). Developed countries deal with the fine-tuning of their already established systems while developing countries are faced with the difficulties of setting up systems that work.

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Effective HCWM requires a systems approach, which enables the effective use of available human resources and development of environmentally sound technologies. Also, financial allocation towards HCWM is a major determinant towards the establishment of working systems for HCWM. For these two reasons developing governments borrow funds to establish working systems and thus accumulate national debt. A huge national debt, however, lowers the possibility of investment in technologies and best practices. Developing countries need to establish affordable systems.

Furthermore, governments of developing countries are slow in agreement at national and regional levels on the appropriate waste management options that must be selected to implement changes in current practices (Rogers *et al*, 2002). There is a need to facilitate decision-making processes in order to speed up the design and establishment of systems

In realisation of how the previous HCWM system is suffering from incompetence, Lesotho has started to change to a new system (Lesotho MoHSW, 2005). The major step has been the identification of existing problems. These were identified by the Ministry of Tourism, Environment and Culture (MoTEC), the Ministry of Health and Social Welfare (MoHSW) and the Christian Health Association of Lesotho (CHAL) during a workshop (Siimane *et al.,* 2005) (report attached as Appendix 2) as follows:

Problem definition:

- HCW is highly infectious (high potential of transmitting HIV and Hepatitis B), but it is not being well managed.
- There is a low awareness of the hazard of HCW by health care staff and the public.
- Remote clinics are under-resourced in terms of funding and skills; therefore there is lack of infrastructure and equipment.
- There is a lack of legal framework on HCWM and the enacted law (Environment Act of 2001) is not operational yet.

- Absence of policies to guide HCWM often leads to non-integration and lack of responsibility at national and sub-national levels.

The health care delivery system in Lesotho is relatively well developed with Non-Governmental Organisations (NGOs) and the churches playing a key role in the most inaccessible areas (Lesotho Ministry of Development Planning, 2000). There are a total of 18 hospitals and 172 health centres (clinics) that are operational (LMoHSW statistical tables, 2003).

A national study on the medical waste situation was conducted (LMoHSW, 2004) to assess the magnitude of the HCWM problem. The findings proved that there is a lack of training in waste handling, absence of funds to construct desired technologies and an overall high but non-quantified risk to waste handlers at facilities. The low level of standardisation also observed in HCWM proves the lack of integration. There is no monitoring and evaluation of HCWM activities in the country. The conclusion from this study is that affordability and feasibility, rather than public health and environmental protection, have been the criteria for selection of HCW handling methods and technologies.

The Lesotho MoHSW has also formulated National Healthcare Waste Management Plans (LMoHSW, 2005), the benefits of which are yet to be reaped. Lesotho is also a signatory of the Basel Convention, requiring that less hazardous waste be generated and that waste is disposed as near to the source as possible. Section seven of the national environmental policy (Lesotho Ministry of Environment, Gender and Youth Affairs, 1996) sets up the intention of promulgating national laws that will implement this convention.

Connelly (2003) points out that movement of political power leads to a change in conceptualisation and commitment to environmental aspects and sustainable development. This has proved to be true for Lesotho's health sector. A change of ministers in the past has brought a new perspective to the way public health protection is perceived. Health care facilities have begun to be seen as nuisance generators regarding waste management and thus their operation is of growing concern.

The issues mentioned above are evidence that improvement is occurring in Lesotho's health care waste management system. It is at this early stage that key priorities must be set and sustainable alternatives selected.

1.3 LEGISLATION AND INSTITUTIONAL ARRANGEMENT IN LESOTHO

1.3.1 Governing Legislation

The constitution of Lesotho

Chapter 3 (section 36) of the Constitution of Lesotho gives direction to the process of sustainable development. It sets out the role of government in ensuring adoption of policies for environmental protection and endeavouring to ensure that present and future generations live in a healthy environment for safety, health and well-being. One such policy is the environmental policy (1996).

Environmental Policy

The policy specifies the country's priorities for protecting and promoting human health as well as the safety of their working places. Section 3.17 requires monitoring the effects and control of all phases of the life cycle of all substances likely to have an adverse impact on human health and the natural environment. Also included is the determination and use of environmentally safe and technologically sound techniques for the disposal of hazardous substances.

Health and Social Welfare policy

The health and social welfare policy identifies environmental health services as the addresser of all potential and actual threats to human health and welfare, by influencing environmental conditions and occupational health and safety of all workers. It does not, however, focus on HCWM as a completion to the cycle of health care provision. The policy lacks a strategy of action for HCWM.

The Environment Act (2001)

The Environment Act of 2001 does not directly address HCWM but hazardous waste in general). It gives the right to a clean and healthy environment for the people of Lesotho. The act stipulates the formation of the Lesotho Environment Authority (LEA) whose activities include the control of HCWM. Applicable sections fall under:

- Pollution control: Prohibition of discharges of hazardous waste into the environment and issuing licenses for pollution (across all media), ionising radiation and effluent discharge.
- Environmental Impact Assessment (EIA): EIA's are required for scheduled activities including treatment of HCW and constructions in health facilities.
- Environmental Quality and Standards (EQS): The LEA can establish EQS for waste as well as air and water quality. Monitoring and auditing of such are the duty of LEA.
- Environmental management: The LEA is mandated to issue guidelines for the management of hazardous waste.

Public Health Order 1970

The Public Health Order (order No.12 of 1970) deals with nuisances in public and private places and specifies the obligation of polluters to pay for the nuisances that they cause. The law is outdated and requires reform to accommodate the current economic activities in the country.

Labour Code Regulations (2003)

The right of workers to a safe and healthy working place is controlled by the Labour Code (Chemical Safety) Regulations of 2003. Although it does not address exposure of chemicals to the public through the environment, certain clauses can be applied to HCW. These clauses address among others, personal protection, labelling and packaging, and training and information for workers.

Urban Government Act (1983)

This Act defines the responsibilities for municipalities and has only been thoroughly implemented in Maseru by the establishment of the Maseru City Council (MCC). The Act mandates urban councils to provide sanitation and refuse collection services within their municipal boundaries. Since the Act does not define hazardous waste, the city's waste disposal system handles mixed hazardous and general waste. The Act is confined to operate in urban areas, which are not the focus of this study.

Sanitary Services and Refuse Removal Regulations (1972)

The regulations were promulgated under the outdated but not repealed Local Administration Act of 1969. Section 14 of the regulations stipulates that waste should not be deposited or stored within public view so as to become a nuisance, injurious or dangerous to health.

A time-line summary of the regulatory framework is presented below:

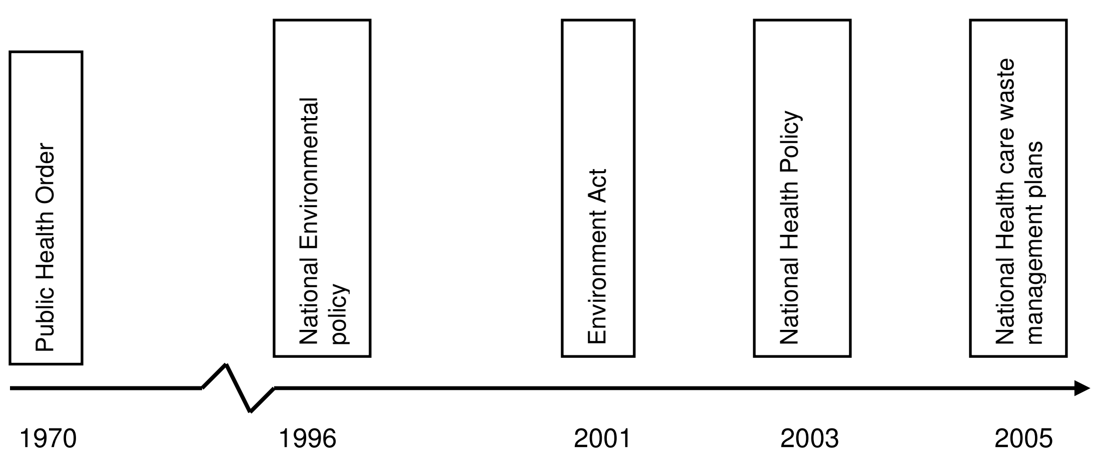

Figure 1.2: A time-line of national legal and regulatory framework for general and healthcare waste management

In summary, there is no legislation in the country to specifically address HCW and its management as well as the consequences brought about by waste treatment technologies; for example, air pollution by incinerators. There has also been no official adoption of foreign standards and guidelines e.g. SABS code of practice for HCRW. The challenge with present laws lies in enforcement of these laws, which is minimal.

1.3.2 Lesotho Institutional Setup and Present Inter-Linkages

All tiers of government should have the responsibility to ensure cooperative governance in order to ensure optimum use of resources and enforcement of accountability (Gauteng Department of Agriculture Conservation Environment and Land affairs, 2004). This calls for the integrated function of government ministries. In Lesotho, hospitals and clinics have traditionally managed their own waste streams through the activities of the diverse departments of the Ministry of Health and Social Welfare (MoHSW). Integration is lacking within the ministry. At district level, the District Health team, which forms part of the District Development Coordinating committee (DDCC), is the responsible body and applies public health interventions like environmental health to address waste management.

The MoHSW has a long-standing partnership with CHAL, which coordinates with government the provision of public health services provided at the health facilities that are owned and managed by churches. In terms of HCWM, there is little collaboration between the two institutions (Brent *et al.*, 2005). Private surgeries are coordinated by the Lesotho Medical Council. They manage their own HCW and very minimal monitoring of their HCWM activities is done (MoHSW, 2005).

The Ministry of Environment and Tourism is mandated with the responsibility of developing policies, action plans and guidelines to protect the environment and assist other ministries dealing with protection of the environment, which includes waste management. This is implemented by the National Environment Secretariat (NES). The line ministries include the Ministry of Local Government

(MoLG), Ministry of Natural Resources (MoNR), and the Ministry of Labour and Employment (MoLE) for the protection of workers.

An advisory committee called the Committee on Waste Management (COWMAN) operates under the NES. Members of the committee represent line ministries, NGO's and parastatals. The COWMAN has no legal power, but advises the LEA, and thus the MTEC, on all aspects relating to waste.

A Committee for Environmental Data and Management Authority, (CEDAMA) has a function of collecting and disseminating environmental data to relevant organisations. It has members from government ministries, parastatals and NGO's. Another important link that exists between the above-mentioned organisations is in the form of a Chemicals Management Committee (CHEMAC) also established under the NES. It is an advisory committee, which deals with environmentally sound management of chemicals in the country.

The HCWM system at hand thus identifies the MoHSW as having an internal role regarding HCW while the MoTEC has an external role. This joint responsibility on a single waste stream does not encourage an integrated approach because their activities are not coordinated via rules of behaviour and allocation of responsibilities. A body with authoritative power needs to coordinate HCW issues between all relevant bodies including bilateral and multilateral agencies.

1.4 SAFETY AND RISK IN HEALTH CARE WASTE MANAGEMENT

1.4.1 Occupational Health and Safety

Environmentally Sound Technologies (ESTs), as part of the HCWM system, should use human and financial resources in a sustainable manner [Agenda 21] (United Nations, 1992). In order to achieve this, employers should protect workers from occupational injuries. The South African code of practice for handling health care waste (SABS, 1993) requires an occupational health programme. Waste workers are evidently still ignorant of the laws in their countries that protect them and still work in conditions that are unacceptable

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according to WHO standards (Pruss et al, 1999). Specially, the use of personal protective clothing is still not practiced in Lesotho. The set of apparel will either be incomplete or the wrong type and material is used (Ministry of Health and Social Welfare, 2004), e.g. the use of clinical latex gloves instead of heavy-duty plastic gloves.

1.4.2 Public Health

According to the Technical Guideline On The Environmentally Sound Management of Biomedical and Healthcare Waste, human health should take first precedence in waste management decisions (Basel Convention,2003). In this way risks posed by HCW to the public should be minimised. Direct risk of injury by sharps transmits disease and if injury can be avoided, infections can be controlled. There are, however, indirect risks involved. For example, treatment of HCW by incineration, which is common in developing countries, releases particulate matter and other atmospheric emissions, which have detrimental human-health effects. It is worth mentioning that developing countries do not have the facilities to monitor and regulate certain, if not all, emissions, especially at the low levels set by the western world (Mc Rae and Agarwal, 1999). Hence setting a strict standard for such emissions becomes a theoretical exercise, and can only be avoided through the adoption of cleaner technologies, processes and practices that promote waste minimisation.

1.4.3 The Risk of Health Care Waste

Health care waste (HCW) poses risk by virtue of having one or a combination of the following characteristics: infectious, flammable, toxic, corrosive, and radioactive or having high oxidising potential (Prüss *et al.*, 1999). Health care waste poses both direct and indirect risks to public health. Wilson (1991) points out that the mere existence of a risk does not imply a problem, but an uncontrolled risk source represents the primary problem.

In Lesotho, the percentage of people infected with HIV/AIDS is 31% (Phaladze *et al*., 2005). Treatment of such patients poses a risk of transmission of HIV to health and waste workers in case of skin puncturing by sharps, e.g. needle pricks. Table 1.1 below summarises the infection risk due to needle prick.

Table 1.1: Infection risk based on needle pricks in sub-Saharan Africa (Kane, 1999).

Disease	Percentage In Sub-Saharan Africa Infected	Infection Risk Based On One Needle Prick	Percentage of HealthCare Workers exposed to viruses*
Hepatitis B	10.0 %	30.0 %	40.0 %
Hepatitis C	2.0 %	6.0 %	40.0 %
HIV/AIDS	> 3.5 %	0.3 %	2.5 %

* (International council of nurses)

A study conducted by Gisselquist (2003) suggests that in Africa, about 10% of the transmission of all HIV is due to the re-use of syringes. Healthcare related exposure is therefore be playing a huge role in HIV transmission.

Almost 85 % of sharps injuries occur between usage and subsequent disposal and more than 20 % of handlers encounter needle prick injuries (McRae and Agrawal, 1999). Table 1.2 below summarises the results of a study done in Jordan. In Lesotho technicians are equivalent to Incinerator operators.

Table 1.2: Needle injury by waste handler category (Mc Rae and Argawal, 1999)

Occupation	Percentage Injured
Staff nurses	34.6 %
Environmental workers	19.0%
Interns	15.7%
Practical nurses	8.5%
Technicians	60.0 %
Residents	11.7%

Technicians and Staff nurses are the groups at greater risk of injury and thus exposure to transmittable diseases. Interventions to avoid injury need to be addressed more towards these groups.

No studies have been conducted in Lesotho on injuries to HealthCare workers related to HCWM.

1.5 RISK ASSESSMENT TOOLS FOR HCW

Risk estimation involves developing quantitative measures of risk (Merkhofer, 1999). Current tools that have been used for risk estimation and assessment include the World Health Organisation Rapid Assessment Tool (WHO RAT) and WHO decision trees. The latter uses procedure based on qualitative approach to minimise the overall risks from managing HCW. It also describes HCWM options that are cost effective. The limits to these tools are their non-user friendliness at practical level for day-to-day application (Rogers *et al.*, 2002).

The WHO RAT quantifies and qualifies waste amounts and general HCWM practices at a facility. The tool was designed such that it encompasses only some aspects of a working system but is low on financial matters. These include budgeting and financing, training needs of staff or equipment requirements. The data thus gathered calls for expert assessment and interpretation in order to provide environmental and budget costs (Rogers et al, 2002). Contrary to the suggestions of Omachuno and Khalil (1988) on factors for evaluating technologies, the RAT does not assess socio-cultural, political, economic and policy alignment of current technologies and practices.

Practices used in HCWM in Lesotho differ widely and cost drivers and feasibility often influence their selection. Each has differing risks of infection to workers, patients and the public (judging from Table 1.2). It is therefore required to place weights and thus calculate risk factors for options such that decision-makers can rank the options and determine the best and most practicable option. This can be achieved by the application of WasteOpt (Rogers and Brent, 2002), which comprises of the WHO RAT and the Analytical Hierarchy Process (AHP).

1.6 THEME OF THE RESEARCH

1.6.1 Research Problem

Lesotho's HCWM system is still in its infancy and opportunities exist for contributions to develop the new system so that it can work in a sustainable manner. A gap has been identified in that there is a lack of appropriate tools that can be effectively applied in Lesotho and other developing countries. A tool is subsequently needed whereby Environmentally Sound Technologies (ESTs) and best practices can be selected to reduce the risk of infection to health care workers and the public due to exposure to HCW.

1.6.2 Rationale and Objectives for the Study

The motive for this research is to fill the gap in knowledge of the risk of HCWM practices in rural clinics. Since very little work has been done on HCW management in Lesotho, it is thus vital that, as strategies are made in the future, they are based on a solid foundation of knowledge. The development and application of the tool, termed WasteOpt, has been proposed (Rogers and Brent, 2002) so as to highlight problems, risks and costs associated with the available options for management of HCW and thus enable the best use of meagre resource available in Lesotho.

The research is based on the following questions:

- Is the developed tool (WasteOpt) suitable for the establishment of HCWM systems that minimise the risk of infection in rural clinics in a cost-efficient manner?
- How can the WHO RAT be modified to supply data inputs that are required for the application of WasteOpt in the field?

The research was therefore driven by the following objectives:

- To develop a tool for sustainable HCWM that is appropriate for developing countries.

- To establish prerequisites for its effective adoption.

These objectives will be achieved by implementing the following activities:

- To apply the workshop component of WasteOpt with experts in waste management in Lesotho.
- To add and modify questions in the RAT so as to improve its assessing capabilities.
- To conduct case studies of rural clinics which assess levels of risk due to HCWM practices.
- To compile the cost for the implementation of EST's and best practices for HCWM in Lesotho.

The major emphasis is on theory application whereby WasteOpt is developed and applied to Lesotho. Theory testing is also researched whereby WasteOpt is tested as a tool to aid decision-making.

1.7 CONCLUSIONS AND RESEARCH STRATEGY

This chapter outlined the background of HCWM in Lesotho as a third world country, in terms of institutional setup and legislative framework in the context of public health protection and occupational health and safety. Thereby, the research problem and rationale has been defined, i.e. there is a lack of appropriate tools that can be effectively applied in Lesotho, and other developing countries, to minimise the risks associated with HCW in a cost-efficient manner. The development of a new tool, termed WasteOpt, is subsequently proposed; by incorporating an existing HCW risk assessment method, i.e. the WHO RAT. The aim is to inform decision-makers on the risk of working with health care waste and the cost effective solutions that can be implemented within a HCWM system.

In Chapter 2, the evolution of waste management from *ad hoc* practices to integrated waste management is discussed. The gap between developed and developing countries is identified in terms of knowledge and approaches to WM.

Lastly a SWOT analysis of applying developed world models and approaches in developing countries is presented.

In Chapter 3 a systems approach and the use of WasteOpt is proposed as a start to the solution of the identified problems.

Chapter 4 outlines the methodology used to carry out the research. After analysis and a discussion of the results in Chapter 5, the thesis closes with conclusions and recommendations in Chapter 6.

CHAPTER 2

Literature review

The scope of this study is restricted to the management of health care waste (HCW) in rural areas of developing countries. The subsequent literature review, however, touches more on general waste. This is due to the extensive research done in the field of general waste, while there is little documentation on HCW, especially in developing countries. There is a correlation between general and health care wastes since they have been managed in unison from as far back as 500 BC (Barbalace, 1999) up until the 1970's in the developed world. In developing countries there is often no distinction between the different sources of waste; it is simply all mixed (International Solid Waste Association, 2002).

2.1 THE EVOLUTION OF WASTE MANAGEMENT

Since the days of primitive society, man has used earth's resources to support life and then disposed of waste (Tchobanoglous *et al.*, 1977). Historically, the amount of waste generated by human population was very insignificant. This was due to the small size and the wide spread of population around the world. There was also very little exploitation of natural resources. Waste was changed into harmless products by the natural assimilative capacity of the earth. When this capacity is exceeded then waste disposal should be controlled so as to ensure sustainable development.

Waste disposal problems can be traced back from the time when humans began to congregate in tribes, villages and communities. At first *ad hoc* disposal onto streets and the countryside led to the breeding of vermin and odour. This situation of medieval Europe can be likened to the situation in most developing countries today. The subsequent bubonic plaque epidemic, cholera and typhoid fever killed half of the European population in the 14^{th} century and caused many other epidemics and high death tolls (Tchobanoglous *et al*., 1977). The year 1750 began the period of industrial revolution. Mass movements of people to the cities led to increasing amounts of waste.

Much activity on waste management came in the 19th century. By the 1800s, households and industries began to have ash pits or ash heaps where onsite open burning of commercial and industrial waste was practiced (Hickman and Eldredge, 1999). Waste generators selected the simplest and least costly method. The link between filth and diseases was made in England in 1842 and in 1888 the English parliament barred waste disposal in public waterways and ditches. The Public Health Act of 1875 was introduced to keep households clean in the UK. The public health approach was then adopted as the motivation to remove waste from the human habitat. In the US the first incinerator for waste treatment was built in 1889 (Barbalace, 1999).

In the 1920s, landfills with semi-controlled burning became a popular method of waste disposal. However, as stated by Hickman and Eldredge (1999), "*A smoking dump is like a smoking gun. It is clear that a crime is being or has been committed*". Hickman and Eldredge further point out that the burning dumps' impact on local air quality was a primary reason that early efforts after World War II were directed towards putting out the fires to control the problem of dumps. Disposal options in the 1950s included incineration, composting, recycling and the sanitary landfill. In the 1960s private contractors came into partnership for collection of waste (Waste Watch, 2004).

It is evident that the bias was still towards end-of-pipe interventions as solutions to pollution. Re-use and recycling were practiced in the middle of the 20th century.

The evolution of a separate category of clinical (health care) waste within the municipal waste stream dates back to the late 1970s, when clinical wastes, including syringes and bandages, were washed up on US east coast beaches (Mc Rae and Argawal, 1999). In many contemporary literatures HCW is still excluded in hazardous waste classification or mentioned in passing. It can be concluded that HCW has not been receiving the attendance it requires.

This history demonstrates that with time man has realised the damage caused by unmanaged waste. He has attempted to remedy the damage (with great costs) and is ultimately shifting paradigms from remediation to prevention. Figure 2.1 illustrates this phenomenon. While the cost of indiscriminate disposal has been constant and low, the costs of remediation and end-of-pipe treatment have been steadily increasing. Remediation is the most costly of all the strategies. Prevention strategies began late in the twentieth century, but their cost has decreased. Hirschhorn *et al.* (1993) explain that by developing new 'control' waste management strategies, short-term improvements in waste management have been achieved.

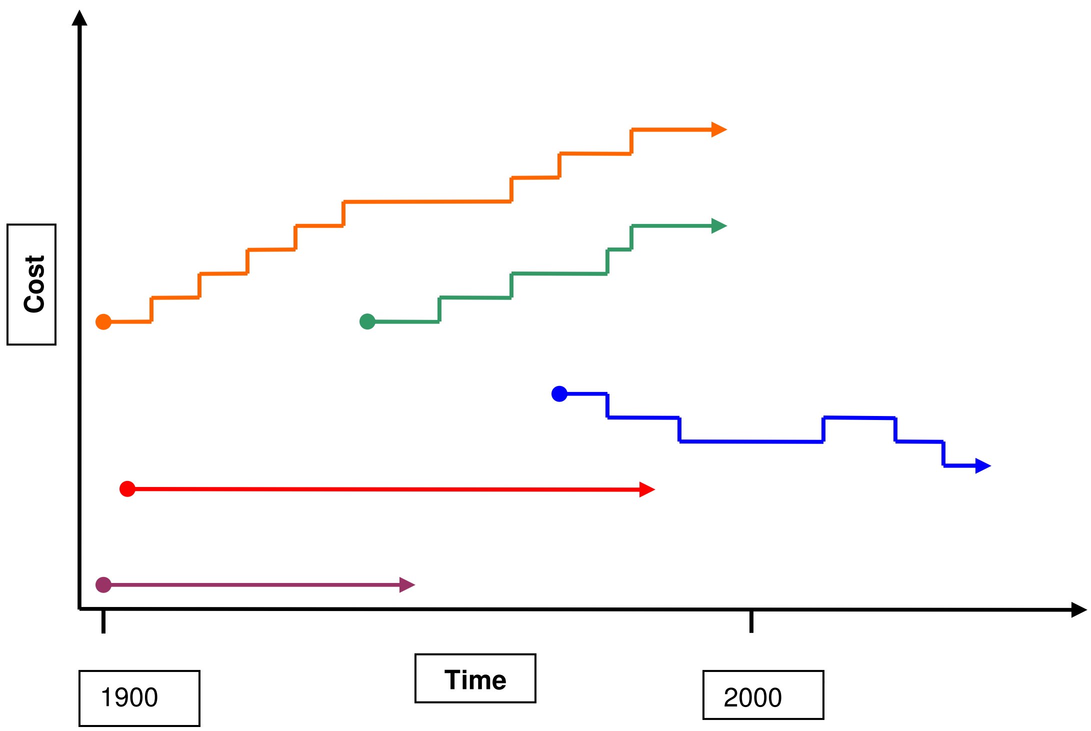

Figure 2.1: Waste management paradigm shifts

Remediation — End-of-pipe treatment

Prevention — Re-direct and sequester/dispose

Laissez faire disposal

Adapted from Hirschhorn, Jackson and Baas (1993)

It should be recognised that despite the different conditions in which industrialised and developing countries must work to solve waste management problems, there are similarities between these countries. In neither case does the public want WM facilities near residential areas and the amount of waste generated is increasing (UNEP IETC, 1996). In developed countries this can be attributed mainly to improved waste statistics collection (ISWA, 2002). In both developing and industrialised countries adopting an integrated approach to waste management is vital (UNEP IETC, 1996).

Cleaner production and consumption has been practiced for more than 12 years in industrialised countries (Kjaerheim, 2003) and this is the field in WM where a major difference exists between the first and the third world countries (UNEP IETC, 1996). It is apparent that one of the best ways to reduce waste is to limit consumption of goods and increase the rate of recovery and re-use of goods. Recovery is not practical in HCWM due to the risk of infection, both in developed and developing countries.

2.2 THE APPLICABILITY OF FIRST WORLD APPROACHES TO THE THIRD WORLD

The first solid waste management models were optimisation models and dealt with specific aspects of the problem (Morrissey and Browne, 2003), for example, the location-allocation model for transfer station siting (Wilson, 1981). Morrissey and Browne (2003) explain that these early models suffered from several shortcomings such as having only one time period, recyclables rarely being taken into account, having only one processing option of each type, or having a single generating source. The limitations thus made them unsuitable for long-term planning.

The following tools and approaches have been used in the developed world and some adopted by developing countries.

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2.2.1 Legislative Tools (End-Of-Pipe and Strategic Targets)

Waste management in developed countries is governed by legislation, which are either end-of-pipe or strategic targets. End-of-pipe regulations, such as emission controls for incinerators, operate as 'fine-tuning' of the waste management system (White *et al*, 1995) because it promotes the use of the Best Available Technologies and practices. Such regulations, however, do not bring major changes to the way that WM systems operate. For this reason, strategic target legislation is increasingly being used to set future strategies based on the hierarchy of waste management (White *et al*., 1995). Such legislation includes the Environmental Protection Act (1990) of the UK and the Medical Waste Tracking Act of 1988 of the USA (Woodside, 1993), which are national laws, and the Packaging and Packaging Waste Directive operating in the European Union (European Commission directive on packaging and packaging waste, 1994) emphasise cleaner production and are backed by enforcement. These legislations, driven by educated pro-active environmental pressure groups and the general public, dictate that waste generators, including health care facilities, operate within acceptable standards. Proper enforcement of these stringent laws makes them highly effective. Due to adherence to legislation, the member states of the European Union (EU) have reached the most advanced state in waste management in the world (ISWA, 2002).

Whereas many countries like Lesotho are still in the process of promulgating specific legislation for waste management, South Africa as a developing country has a number of first world regulations ands standards, e.g. the Environmental Conservation Act (1989), the National Water Act (1998) and the National Environmental Management Act (1998). Standards include Water quality standards. However, the biggest challenge facing the country is the lack of enforcement. Hill (2004) and Friend (2001) agree that this is due to insufficient funding. Hill also blames weakness in governance and corruption.

This approach therefore can only benefit developing countries if more people and institutes become aware and strive for positive publicity and become threatened by negative publicity. This will increase compliance.

2.2.2 Economic/Market-Based Tools

The application of economic tools for waste management uses the proverbial carrot while legislation relies on the stick. These two work best when put together. This approach better summarised as “the polluter-pays principle” offers a system of penalties and rewards. Taxes and fees are paid to government and service providers respectively for environmental degradation (pollution) and for services rendered for the disposal of wastes (SA DEAT, 1993).

Cost-benefit analysis (CBA) enables decision-makers to assess the positive and negative effects of a set of scenarios by translating all impacts into a common measurement, usually monetary. The tool estimates the costs of avoiding a negative effect, e.g. the cost of pollution control or to establish how willing individuals are, to pay for an environmental improvement (Morrissey and Browne, 2003). The problem with CBA lies in the uncertainty of using monetary units on environmental and social impacts. Assumptions of prices may also change with time, impacting on the waste management programme. CBA is being used in developed and developing countries like South Africa.

Green marketing is also a relevant tool that focuses on the environmentally educated consumer. Products that are packaged in recyclable or refillable materials decrease the amounts of waste disposed of and are thus preferred. This concept is linked to Environmentally Preferable Purchasing (EPP) for Health Care Facilities and is widely used in the western developed world (USEPA, 1999), in realisation that correcting a problem close to its source is safer and less costly than taking action downstream. By purchasing products/services whose environmental impacts have been considered and found to be less damaging to the environment and human health, health care providers benefit by:

- providing a healthier environment for patients, workers and employees through reduced exposure to cleaners, solvents, paints, and other hazardous materials;
- reducing costs by lowering overheads, avoiding waste disposal, liability and occupational health costs; and
- significantly improving their impact on the overall quality of the environment while also leveraging positive publicity (USEPA) .

Purchasing, being a money transfer stage and contract development is an effective point to apply actions to improve public health safety and environmental impact because suppliers can best be influenced.

Economic tools are not widely used in developing countries due to lack of appropriate goals and policies. Also, heavy taxes on large populations that can ill afford to pay for basic needs may be regressive to them (Hanks and Hobbs, 1991).

2.2.3 Mathematical Models

Models such as location-allocation and selection-allocation have been proposed in the past as an aid to waste management primarily for strategy evaluation (Wilson, 1981). Location-allocation has been used to determine optimal sizes, numbers and location of hazardous waste management facilities, given transportation and processing costs. This model thus compares the cost of having large, centralised facilities against the cost of smaller, decentralised facilities (Sewall, 1990). Many of these models are complex and a lot of time is spent trying to solve the model more than relating the results thereof to the problem (Wilson, 1981). Such models are also data intensive, which makes them unsuitable for third world countries where there is a large deficit of data. Wilson goes on to point out that this data deficit leads to waste coefficients being estimated from a small survey sample or analogy into national averages, giving unreliable results.

2.2.4 Life Cycle Analysis Models

Life cycle analysis (LCA) as a comparative tool for environmental impacts is recently being used to compare waste management strategies (Morrissey and Browne, 2003). Powell (2000) has shown that decision-makers who use LCA models end up focusing more on financial issues due to the complexity of such models. The failure of Environmental LCA (ELCA) to assess health impacts, social, economic and time dependent impacts make it inadequate for WM strategy choices in developing countries. Environmental Impact Assessments cover these impacts but are also difficult to perform. Despite the shortcomings of LCA-based models, they tally with integrated waste management by attempting a holistic approach.

2.2.5 Models Based On Multi-Criteria Decision-Making

When used in WM, these models have focused on the decision-making process rather than identifying the problem (Morrisey and Browne, 2003). ELECTRE, an integrated solid waste management model, has been used in Finland by Hokkanen and Salminen (1997) in choosing a solid waste management system. It is helps in decision-making for multiple criteria in identifying alternative WM strategies that meet cost, energy, and environmental emissions objectives. Karagiannindis and Moussiopoulos (1997) applied AHP in integrated municipal waste management. The application of AHP in developing countries has been encouraged by Alphonse (1996) but application has not been wide.

2.2.6 Integrated Waste Management

Integrated Solid Waste Management (ISWM) was first grasped by the developed world in the 1600s. However, it was seldom used in the developing countries of Africa until the 1900s when the Zabbaleen family of Egypt first integrated recovery and recycling of waste (Mvuma, 2002). Since the publication of 'Our Common Future' (WCED, 1987), waste management issues have been examined within the broader context of sustainable development, which attempts to reconcile the concerns of environment, economy, and society (White *et al*,

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1995). Existing waste management hierarchies like the four R's (reduce, reuse, recycle, and recover) have dealt with the physicochemical, energetic, and material conservation aspects of waste management effectively, but have not dealt well with the socio-political and biotic aspects of waste management very well (Brown, 1999). These concerns include informal sector waste-pickers whose low earnings from waste can support families. In order for a waste management system to be effective it should be environmentally, socially and economically sustainable and it is likely to be integrated. According to Watkins (2000), in an integrated system, units at different levels should plan simultaneously and together because decisions taken at one level will usually affect other levels. ISWM entails the establishment of one system which :

- management of all types of waste;
- impact assessment across all media (water, air and land); and
- involvement of all stakeholders including the includes public.

The UNEP supports this approach and mentions that this approach has become important because it allows for full utilisation of resources and thus helps in achieving economies of scale. It incorporates all sectors, including informal ones and ensures coordination of all waste management activities.

2.2.7 Informative Instruments

There is a continuing need for research and technology transfer between countries (ISWA, 2002). Exchange of experience has mainly been taking place between developed countries, or between developed and developing countries. Wassersug (1998) also points out that European countries have learnt much from the practices and mistakes of the western developed world. A need arises also to share information between developing countries.

In many countries, education and awareness raising initiatives are launched as part of public participation. ISWA (2002) emphasises the importance of public participation in projects before their realisation. Special consideration is to be given to those projects that will impact on the lives of the public. An informed citizenry would result in pressure upon facilities to act where reliable data warrants such action (Wassersug, 1998).

It is crucial for a country to have an effective and competent workforce at all levels of waste management. The problem with developing countries is the lack of academic programmes to achieve qualifications in waste management (ISWA, 2002).

Of equal importance (for information acquisition and dissemination) for developing and developed countries is the issue of environmental reporting (ISWA, 2002). This clear and systematic manner of reporting is a crucial way of sharing information between companies and government and between countries at country level to encourage improvement in diverse environmental fields, including waste management.

The issues mentioned above have worked for developed countries. Many developing countries are adopting this information strategy. South Africa and Lesotho are examples. South Africa has learnt lessons regarding the selection of inappropriate approaches and techniques in involving stakeholders in projects. They have therefore prepared guidelines and best practice manuals for different stakeholders. The South African Department of Environmental Affairs and Tourism (2002) has realised that *"[a]pproaches and tools should be selected to achieve effective….stakeholder engagement and not only to meet minimum regulatory requirements.*"

The following are examples of projects that tried to adopt first world approaches but were unsustainable (Palmer Development Group, 1996):

Lagos, Nigeria (1977)

The Lagos state refuse disposal board was established to deal with escalating waste problems. New vehicles and expatriate technical assistance were procured to manage the operation. In 1984 the expatriate contract expired and Nigerians who had limited engineering and waste management design knowledge ran the board. Due to inadequate funding, staffing and equipment, the board's operations became less planning oriented and ended up only dealing with day-to-day crises management.

Antananarivo, Madagascar (1984)

A World Bank project was destabilised due to differences between government and an overseas supplier of waste collection vehicles. The government charged duties and taxes on the import of these vehicles leading to the supplier refusing to provide spare parts for maintenance until it was reimbursed the taxes. Three years later 11 of the 23 trucks were out of service due to lack of spare parts.

Cairo, Egypt

The Zabbaleen contractors had been practicing waste recovery by house-to-house collection in Egypt. However, they discovered it was more profitable to collect refuse from wealthy neighbourhoods and thus neglected the poorer ones. This inequity in service provision resulted in inefficient resource recovery.

The cases above depict the difficulties facing developing countries: the option to apply first world approaches and technologies is attractive because of project funding from first world countries as well as the success of the application of the approaches in the developed countries. But the necessary know-how, know-why and the partnership for monetary gain as the primary focus require large investment/resources (Khalil, 2000).

2.3 A SWOT ANALYSIS OF APPLYING DEVELOPED WORLD MODELS AND APPROACHES IN DEVELOPING COUNTRIES

The SWOT analysis is divided into internal and external analyses. Tables 2.1 and 2.2 present the strength, weaknesses, opportunities and threats that result from applying the models and methods in the developing country context from a government and community perspective, while Table 2.3 analyses the same factors from the perspective of external assistance by bilateral and multilateral agencies.

Table 2.1: Government (internal) analysis*

Factor	Strengths	Weaknesses	Opportunities	Threats
❑ Development implementation	1. Implementing such approaches exposes poorly knowledgeable officers of the trends within the developed world	1. Stringent laws are not set in developing countries due to the difficulty of law enforcement, which requires monitoring and evaluation. Present laws are fragmented	1. The restructuring of government administration from centralised to de-centralised approach	1. National and local governments often adopt strategies in a vacuum before they examine their own waste streams and cap-abilities
❑ Process for legal reform	2. There is usually a solid support, either financial subsidy or technical expertise from bilateral and multilateral aid agencies	2. There are often no clear roles or functions of the various national agencies defined in relation to WM and also no single agency or committee with authority designated to coordinate projects or activities	2. New acts can be formulated and old ones updated	2. Action to adopt certain strategies is very slow
❑ Planning and integration	3. Top-down planning is continually being strengthened for more focused decision-making	3. Lack of integration of waste management practices and unclear jurisdiction boundaries causes systems not to	3. Private-public partnerships are being encouraged and can be adopted	3. Funding is highly competitive for the likes of health, infrastructure, national security, etc

		have clear decision-making powers and feedback		
❑ Implementation and strategy action plans	4. The government has the sole power to formulate new rules, acts and new ordinances for strict implementation of proper MSWM	4. Research and development activities in waste management are often a low priority due to lack of plans in developing countries		4. Lack of plans and integration encourages piece-meal assistance from donor agencies
❑ Training	5. Some governments like Lesotho have started training personnel in different disciplines of environmental sciences and engineering to deal better with waste management issues	5. At local level there is particularly little or no training in engineering or management		
❑ Value systems		6. Low work ethics and thus poor work quality are often exhibited by waste workers due to social perceptions of the job		
❑ Technology use		7. In technology transfer from industrialised countries, highest technology is sought		

		where medium –level technology would be appropriate to the available resources [1]		

*Adopted from Ogawa (1996) and Srivastava *et al* 2005
[1] Omachuno and Khalil (1988)

Table 2.2: Community (internal) analysis (modified from Srivastava *et al*, 2005)

Factor	Strengths	Weaknesses	Opportunities	Threats
❑ Community-Based Organisations	1. Many communities have community-based organisations (CBO's) in place who aim to develop society	1. People depend on the government to take action	1. Non-governmental organisations (NGO's) usually support many CBO's	1. Poor inter-sectoral communication and coordination confuses and demoralises the public
❑ Community groups	2. Youth and students have active groups which can participate	2. Some communities are unwilling to participate in waste management	2. Unemployed community members can participate and gain knowledge	2. Community programme or project sustainability is poor in developing countries
❑ Community groups	3. Housewives and the active elderly groups are easily involved	3. Lack of information and environmental awareness in the communities leading to misunderstanding and apathy	3. Self-help and self-reliance can be achieved	

			4. Mobilisation can be achieved by awareness training and information, education and communication (IEC) leaflets	

Table 2.3: External support analysis (adopted from Ogawa 1996)

Factor	Strengths	Weaknesses	Opportunities	Threats
❑ Donor agencies	1. There is an abundance of technical expertise and human re-sources in waste management in external donor agencies	1. Human resource base lacks experience and knowledge of WM for developing countries	1. Developing countries are striving towards global cleaner production and thus external donor agencies have an interest to assist	1. Communication between external support consultants and local counter-parts is often a problem (no common spoken language)
❑ Technology transfer		2. There is a tendency of donor countries to support technologies available or invented in their countries regardless of its applicability e.g.	2. Research and development activities in external donors may be focused on waste management in developing countries	2. Waste management may not be a priority sector for some donor agencies

		obsolete equipment		
		3. Many technologies are tested and designed under developed country conditions, e.g. dependability on electricity, leading to unsustainable use of such in developing countries		3. Recipient countries often receive what-ever aid is rendered even if it is in-appropriate
❑ Integration coordination and finances		4. External support agencies are often not coordinated in a country due to organisational mandates		4. Solid waste management does not often generate revenues and the risk of a loan for such a project is seen as high by external lending agencies

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The biggest problems arise from the weaknesses due to the country's internal operation. The pressures from external agencies further worsen this. There seem to be less opportunities and strengths. These are the areas that need attention in waste management planning: creation of opportunities and elimination of sources of weaknesses and alteration of threats into opportunities.

2.4 THE WASTE MANAGEMENT GAP BETWEEN DEVELOPING AND DEVELOPED COUNTRIES

Developing countries are at an advantage by being followers of developed countries' initiatives, since they can try to avoid the mistakes made by the pioneering countries. However, due to the more rapid advancement of WM in developed countries relative to the developing world, a gap in knowledge is realised. Third world countries can learn to minimise this gap to make WM successful. Wassersug (1998) mentions the following points as critical issues for effective development of waste management systems in developed countries that can be used to show the way forward for developing countries.

2.4.1 Information

Today the developed world has information that enables better decision-making by managers. Improvements in science and technology allow better monitoring of waste management and research has yielded a better understanding of health and environmental impact. Compliance to set regulations requires comprehensive information e.g. waste quantities, qualities, sources, etc. and this information has been used to develop effective waste management strategies in developed countries. The sharing of information within regions also strengthens waste management.

Developed countries manage their information better in order to avoid its scattering and poor organisation. This makes information easy to access (Omachuno and Khalil, 1988)

2.4.2 Enforcement and Compliance

Solutions to waste problems are often costly, and therefore do not lead to voluntary compliance. To be successful, compliance programs are based on sound principles and benefits. Legislation and control play a pivotal role in developed countries. The trade-off that exists between costs and risk are balanced by policies and legislation.

2.4.3 Private-Public Partnership

In the Western world, some of the success of hazardous waste management depends upon the existence of a private sector that makes its profits from handling and managing wastes. This increases the competition to do business, while in the process waste is effectively managed.

2.4.4 Public Involvement

Information gathered by facilities and governments to define environmental impact is routinely required and freely available to the public. Communications between all the diverse interest groups exists and is frequent. They are given information for environmental awareness and frequently are able to on an informal basis to develop and plan individual compliance strategies.

2.4.5 Technology

Before a country can adopt a technology it has to perform systematic analyses to assess financial affordability, capability of present infrastructure so as to develop national priorities (Eldin, 1988). This requires extensive information on technology that is often lacking in developing countries. Developed countries are at an advantage because of an abundant skilled workforce who can perform the analysis of technology without the assistance of expatriates. Unlike the developed world, some developing countries do not have abundant skills to assess and acquire foreign technology as it suits donors (Omachuno *et al*, 1988). This often leads to the acquisition of inappropriate technology. Furthermore, as the result of trends that shorten of the technologies' life cycle sees transfer of outdated/inefficient technologies to the developing world (as donations or products on the market) these can work against countries' environmental objectives for sustainability.

Developed countries have skilled labour and capital, which render their technologies appropriate. The lack of these factors in developing countries sees them opting for inappropriate technologies. Labour-intensive unsophisticated technology is appropriate for such countries although lack of skills hampers their optimal use (Omachuno *et al*, 1988).

2.4.6 Financing

Proper budgeting for waste management is vital in the integrated system. To assist financing these activities, developed countries have the advantage of using locally made equipment, which can be cheaper and be more appropriately designed for prevailing conditions. They can also evade the cost of import and other taxes. Rich countries have high labour costs and sometimes importing equipment may be cheaper due to currency strength.

2.4.7 Implementing strategies

Omachuno and Khalil (1988) mention the divergent conditions prevailing in different developing countries. There is therefore no single pattern, technology or approach that can be considered as appropriate for all. Seen in this light, it is evident that waste management models and approaches from the developed world are not necessarily applicable to developing countries. It is vital, therefore, to devise strategies of either

- updating current waste management standards to those of developed countries; or
- developing new approaches and tools that are applicable and sustainable in poor countries.

In summary, many models recognise that, for a waste management model or strategy to be appropriate, it must consider environmental, economic and social aspects. No model or approach examined here has considered all three aspects together as well as the intergenerational effects of the strategies proposed (Morrissey and Browne, 2003). Furthermore, these models rarely consider the involvement of all stakeholders, including communities.

2.5 CONCLUSIONS

Many tools have been developed and applied effectively in the first world. They do not necessarily prove to be perfectly applicable to developing countries due to the different conditions under which they are applied. Therefore, an effective model for WM in developing countries must be developed following the key principles mentioned above.

In addition, for such a model some tools developed in the first world can be modified for use in a developing country, i.e. the WHO Rapid Assessment Tool (see Section 1.5 of Chapter 1). The formulation of the model and its applicability is described in Chapter 3.

CHAPTER 3

Theoretical setup

3.1 INTRODUCTION

This chapter presents the WasteOpt model which is applied to realise the ultimate goal of the research. The systems approach to problem solving is introduced first and its relation to WasteOpt is highlighted. Emphasis will be put on the Analytical Hierarchy Process and life cycle management (LCM), which constitute WasteOpt. At the end of this chapter, the conceptualisation of the model (consolidation of AHP and LCM) is elaborated in detail.

3.2 THE SYSTEMS (HOLISTIC) APPROACH

A system has been described as " *a set of parts coordinated to accomplish a set of goals*" (Churchman, 1983), and "*a group of interacting, interrelated or interdependent elements forming a complex and unified whole that has a specific purpose*" (Lannon-Kim, 1994). Both these definitions acknowledge two vital points about a system:

- It is composed of a group of parts or elements; and
- the parts or elements work in unison towards an ultimate, realisable goal.

The system can be considered as an input-output model as shown in Figure 3.1. Superimposing feedback onto the basic model (Figure 3.2) renders the system controllable in terms of inputs (Wilson, 1974). The viability of the system also depends on the capability of the system to respond to threats and opportunities from its environment, regardless of whether these were foreseen at the design of the system (Jackson, 2000).

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Figure 3.1: The basic input-output model (adopted from Wilson, 1974)

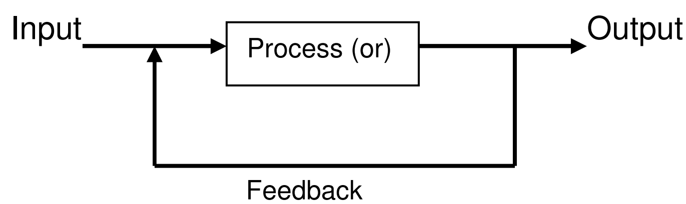

Figure 3.2: The basic system with feedback loop (modified from Wilson, 1974)

The systems approach (also called holistic approach) is the most popular problem-solving technique today (Jackson, 2000). It is favoured [for application in waste management issues] over its counterpart, systems analysis, because the latter is useful for revealing *how* a system works while the former exposes *why* a system works the way it does (Watkins, 2000). The applicability of the systems approach can be challenged since waste management systems are composed of subsystems over which no single person has overall control (White *et al,* 1995). The advantages of the systems approach outweigh this challenge and are as follows:

- It provides an overall picture of the waste management process, which is essential for strategic planning.
- Since all waste management systems are parts of the global ecosystem, reductions of certain unwanted parameters of the system (e.g. land pollution) could bring greater impacts elsewhere. Changes in consumption for example can have a reduction in pollution.
- Economically financial incomes from waste management must at least match the expenses. Through this approach, each boundary of operation [sub-system] can be checked for inefficiency and thus the efficiency of the whole system (White *et al*., 1995).

The holistic approach is also connected to a form of synergistic impacts, which comes from a general thesis of wholes: "*the whole is more than the sum of its parts*" (Encyclopaedia of Educational Technology, 2004). White *et al*. (1995) point out that a holistic approach is environmentally and economically sustainable. One can extend this observation to include socially sustainable. They further explain that looking at different related parts individually leads to inefficiency due to duplication of efforts.

According to Athey (1984) and Beck (1973), the systems approach to solving problems is based on [but not restricted to] the following steps:

- Define the problem;
- gather the data describing the problem;
- identify alternative solutions [within the system identified];
- evaluate these alternatives [to meet objectives of the system];
- select the best alternative [based on criteria that prioritise multiple objectives of a system]; and
- follow up to determine if the alternative is working.

The above points are encompassed in this research study. The selections of the best alternatives, as well as the follow-up, fall within the implementation of the research. It is therefore proposed that a systems approach in the developing country context is required as a basis for the development of an appropriate waste optimisation model. The Water Research Commission (1995) identifies a holistic approach for developing countries to constitute of the following:

- Institutional arrangements
- Appropriate systems
- Finance
- Community involvement

The above-mentioned points tally with what Wilson (1974) and Tchobanoglous *et al. (*1977) refer to as elements of a system, to which they add components such as objectives, reporting and accounting, as well as operations. Reporting and accounting can be related to feedback in Figure 3.2, which allows inputs to be controlled in relation to measured output (usually a predetermined standard). All subsystems of HCWM (health care waste management) should be managed to optimise the operations. It is therefore important to implement a model that leads to the adoption of an optimised systems approach. WasteOpt is the proposed model.

In comparison to the systems presentation in Figures 3.1 and 3.2, WasteOpt is illustrated in Figure 3.3 below.

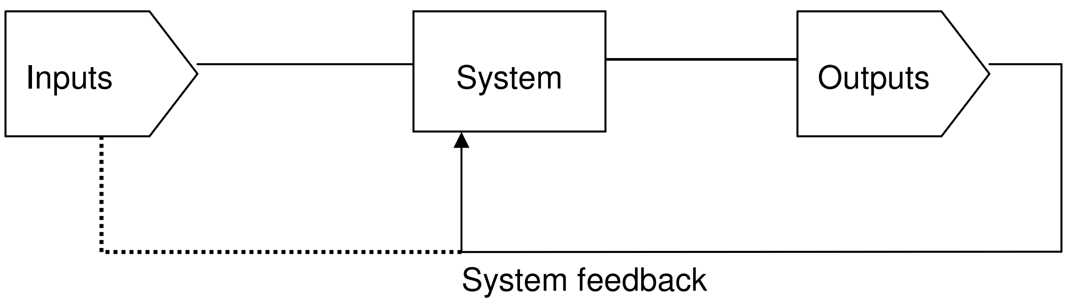

Figure 3.3: WasteOpt presented as a systems approach

WasteOpt‘s application in this study is not to redesign the system but optimise its functionality by optimising the use of scarce resources. The inputs are to an extent limited to the availability of resources, so the system feedback changes are directed towards the functioning of the system. The functionality of the system adjusts to the inputs and can operate in a sustainable manner with the limited resources.

WasteOpt can be applied to waste management in resource poor countries in two parts, as discussed below.

PART A: The selection of Environmentally Sound Technologies is based on reducing risk using the following activities

The system inputs are:

- A database of available technologies (options), prepared by an expert and a survey of the facilities and equipment subsystem).

- A representative working group of the human resources subsystem which has the role to compare options. It comprises of nurses, environmental health practitioners, waste management control and pollution control practitioners.
- An independent facilitation team that is not part of the system .It includes the participation of waste management experts whose role is to describe the system in terms of tasks and available technologies.

The WasteOpt's outputs to allocate priorities to combinations of available technologies are:

- A ranking of acceptable risk of each unit task, divided into equipment, procedures and manpower.
- The identification of optional activities.

PART B: The preference of Environmentally Sound Technologies (ESTs) is based on cost/finances.

The inputs are:

- Cost analysis for preferred ESTs.

Outputs:

- Ranking of costs for ESTs that are similar or near to similar ranking in safety.

The views of Clark and Augustine (1992) and those of Forrester (1972) are taken to validate the WasteOpt tool's applicability.

- Clark and Augustine are of the opinion that "*to pursue a modelling methodology, we must identify a complete and relevant set of information attributes, assign different dimensions to these attributes and test the performance of the system on these several dimensions*".
- Forrester says, "*the obvious purpose and test of a model of an industrial system is its ability to predict a specific future action*". From this statement Watkins (2000) draws an analogy that the quality of input to a model has a direct bearing on the model's ability to predict future action accurately.

It is therefore the objective of this dissertation to verify that the WasteOpt is applicable to the design of a waste management system in rural health care facilities of Lesotho. The method of verification is the outcome of the model that will direct action towards improved waste management of health care waste. The considerations for a systems approach for HCWM are diagrammatically represented in Figure 3.4. Figure 3.4 is based on an ideal situation, which is what developing countries should strive to achieve.

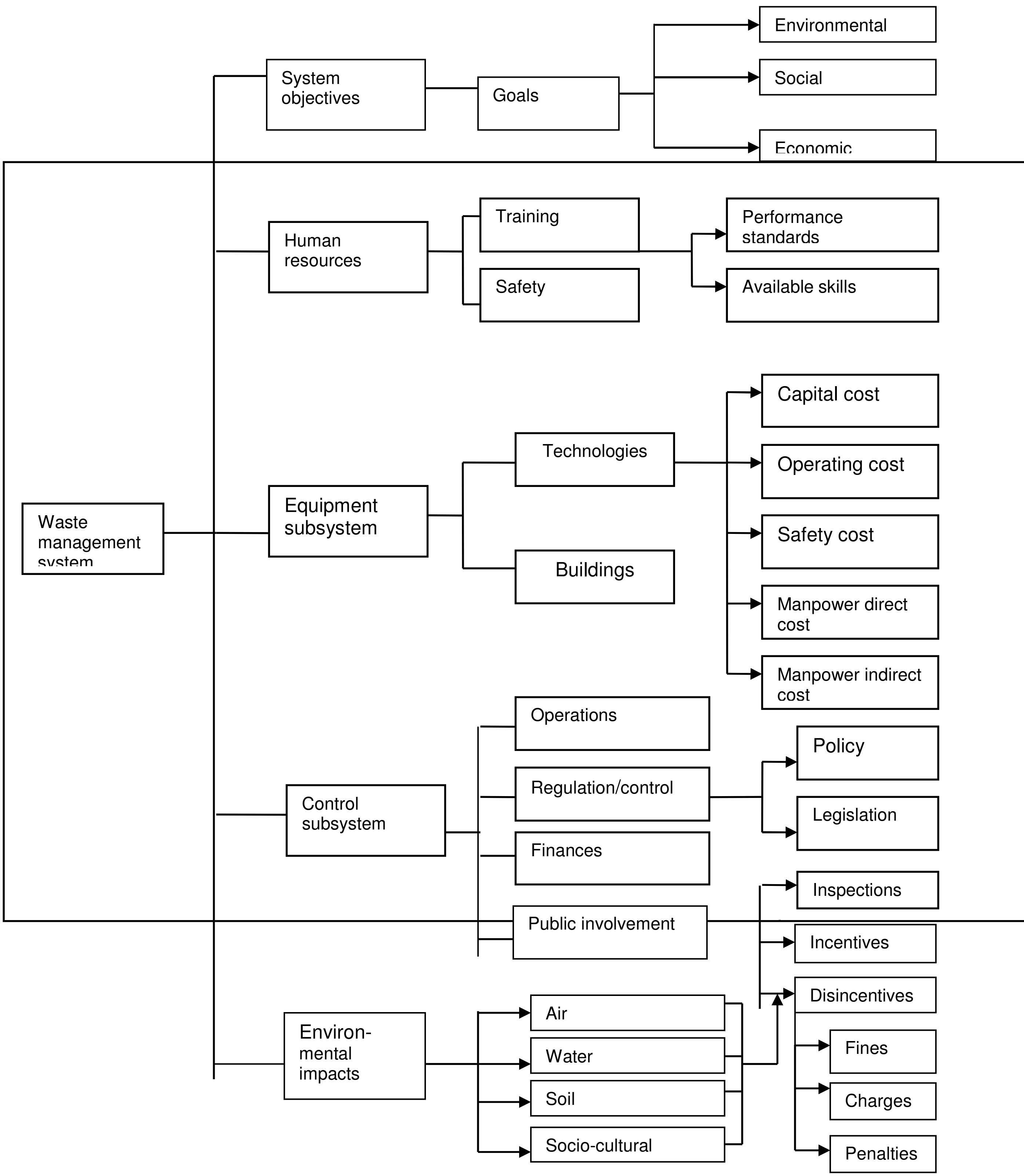

Figure 3.4: The systems approach to waste management

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3.3 THE USE OF AHP AND ENVIRONMENTAL LIFE CYCLE DECISION SUPPORT TOOL

WasteOpt is based on the combination of two well-known decision support tools: the Analytical Hierarchy Process (AHP) to establish priorities and Life Cycle Management (LCM), and specifically Life Cycle Assessment (LCA) and Costing to identify technical options for HCWM. The benefits of both processes are shown in Table 3.1.

Table 3.1: The benefits of LCM and AHP

Life cycle Management	Analytical Hierarchy Process
1. LCM includes all inputs and outputs and procedures of a system, over time and overall space. 2. Quantitative outcomes ensure the exclusion of emotions in decision-making. 3. Encompasses all sustainability issues pertaining to a system	1. Does not insist on consensus but synthesizes a representative outcome from diverse judgements 2. Considers priorities of factors in a system and enables the selection of the best alternative based on goals. 3. Offers a scale for measuring intangibles and a method for establishing priorities. 4. Integrates deductive and systems approaches in solving problems • Reflects the natural tendency of the mind to sort elements of a system into hierarchies while also tracking the logical consistency of judgements used for determining priorities.

WasteOpt combines LCM and AHP in a unique way. The model shifts from AHP to LCM and then to AHP. WasteOpt encourages the construction of multiple hierarchies for each life cycle phase as opposed to a single hierarchy (see 3.4.1 below). This is because the AHP requires attributes at level 1 to be independent of each other. In the case of HCW, the life cycle phases (which are level 1 attributes in the hierarchy) are related. Figure 3.5 below summarises the WasteOpt shifts.

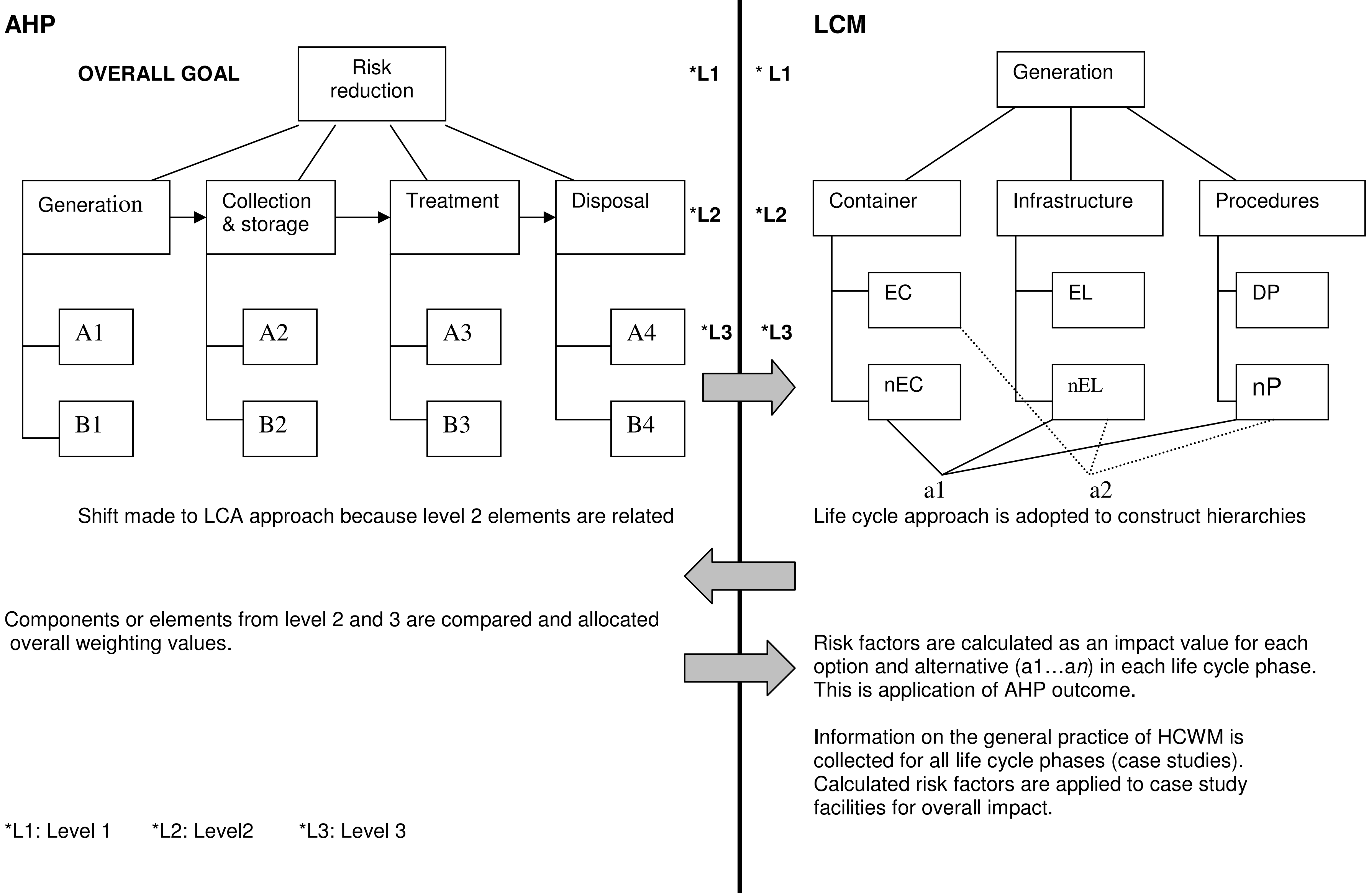

Figure 3.5: The AHP and LCA as combined by WasteOpt (example for the generation life cycle phase)

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3.3.1 The Analytical Hierarchy Process (AHP)

For the application of the AHP all stakeholders (as stipulated in Section 3.3 above) in the system are required to participate. Their role is to define the goal and scope of the system, consider the inventory data (from, for example, the WHO Rapid Assessment Tool), and participate in the impact assessment (setting of priorities to calculate risk scores). It is then up to the decision-makers of the HCWM system to choose the most appropriate life cycle alternatives.

The step-by-step methodology of the AHP as devised by Saaty (1980) is given below.

Step 1: Setting up the hierarchy

The problem is first structured into a hierarchy of three levels or more. The first level is the overall goal of the decision-maker. The second level consists of factors that contribute to the goal, while the third level denotes the alternatives or options available for application. Saaty (1986) explains that the elements in each level should be clustered into homogenous groups so they can be meaningfully related to elements in the next higher level. Any element in one level must be capable of being related to some element in the next higher level. An example of a hierarchy for the generation phase is shown on the LCA side of Figure 3.5. Hierarchies for other life cycle phases can be found in Appendix 4.

Step 2: Setting the priorities

In this step, the priorities for each element are established within each level. Saaty proposes the pair wise comparison to compare the factors, i.e. the factors are compared in pairs against a given criterion. The preferred form for the comparison is a matrix, for example, in Figure 3.5, level 2, elements (container, infrastructure, procedures) are compared for importance in respect of achieving the overall goal. In this study the overall goal is to minimise the risk of infection due to HCW. A judgement of how important each element is compared to another element is made by asking a question such as, *"How much more strongly does this element contribute to, dominate, influence, satisfy or benefit*

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the property than the one to which it is being compared"? (Saaty, 1986). The exact AHP question for the study is shown below.

> *"How much more important is each option compared against the other in terms of minimising infection risk?*

Saaty proposes the use of an ordinal scale of 1 to 9 (-9 to +9) and the results are filled out in a matrix since it uniquely reflects the dual aspects of priorities, i.e. dominating and dominated.

A sample matrix for the tree in Figure 3.5 is presented below.

Table 3.2: Sample matrix for pair wise comparison

	Container	**Infrastructure**	**Procedure**
Container	1	4	3
Infrastructure	1/4	1	1/2
Procedure	1/3	2	1

Step 3: Establishment of the Eigenvector

Comparisons of each element against itself result in unity and the remaining ones are reciprocals of the first judgements. The reciprocals hold true only when the matrix is consistent[1] (Saaty, 1980). From the matrix, the Eigenvector is computed and normalised to yield a vector of priorities. Saaty proposes four methods for calculating this vector. The methods increase in complexity and accuracy from 1 to 4. WasteOpt is based on the third method, but this thesis focuses on the fourth method in an effort to increase accuracy. These methods are briefly described.

[1] Consistency is a statistical measure of the extent to which an individual's decision structure, i.e. set of assessment judgements, is closer to being logically related than randomly chosen. The consistency of judgements reflects the extent to which the decision-maker(s) understands the problem, is knowledgeable of the decision variables involved, understands the assessment process, and is able to make a series of logically related judgements based on uncertain and often incomplete information.

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Method 1: Elements in each row are summed. To normalise, row sums are then added to get a single figure. The single figure then divides each row sum such that the resultant figures add up to unity.

Method 2: Elements in a column are added and then converted into reciprocals. Normalisation is achieved by dividing each by the sum of reciprocals.

Method 3: Each element in a column is divided by the sum of the column (normalised). The resultant rows are averaged (added and divided by the number of elements in a row).

Method 4: *n* elements in a row are multiplied together and the *n*th root of the product taken. Normalisation is then done.

The normalised columns are shown in Table 3.3.

Table 3.3: Normalised columns

	Container	**Infrastructure**	**Procedure**
Container	0.63	0.57	0.67
Infrastructure	0.16	0.14	0.11
Procedure	0.21	0.29	0.22

The geometric mean of the rows is then computed to give the Eigenvector. Saaty (1986) uses the average, but the geometric mean is used in this study in an effort to reduce the effect of outliers on the result (Aull-Hyde, Erdogan and Duke, 2004). The Eigenvector for this example is **0.625** for container**,** **0.136** infrastructure and **0.240** procedure.

Step 4: Comparison of options

In this step, the decision-maker moves to the next higher level, e.g. level 3 in Figure 3.4, and compares the options in that level in terms of the ones on level 2. The Eigenvector is calculated for these comparisons. With this Eigenvector overall ranking is thus performed to select the favourable alternative. The matrices for level 3 comparisons are shown below:

Container	EC	nEC	Eigenvector
EC	1	7	**0.875**
nEC	1/3	1	**0.125**

Procedure	DP	nP	Eigenvector
DP	1	6	**0.857**
nP	1/6	1	**0.143**

Infrastructure	EL	nEL	Eigenvector
EL	1	8	**0.889**
nEL	1/4	1	**0.111**

Figure 3.6: Matrices for level 3 comparisons

Step 5: Establishment of overall weighting values

The overall weighting values for the options are calculated by multiplying the determined weighted values (Eigenvectors) of level 3 by the Eigenvector of the level 2 component to which the option belongs. Figure 3.7 illustrates the Eigenvectors (weighting values) for elements in all levels.

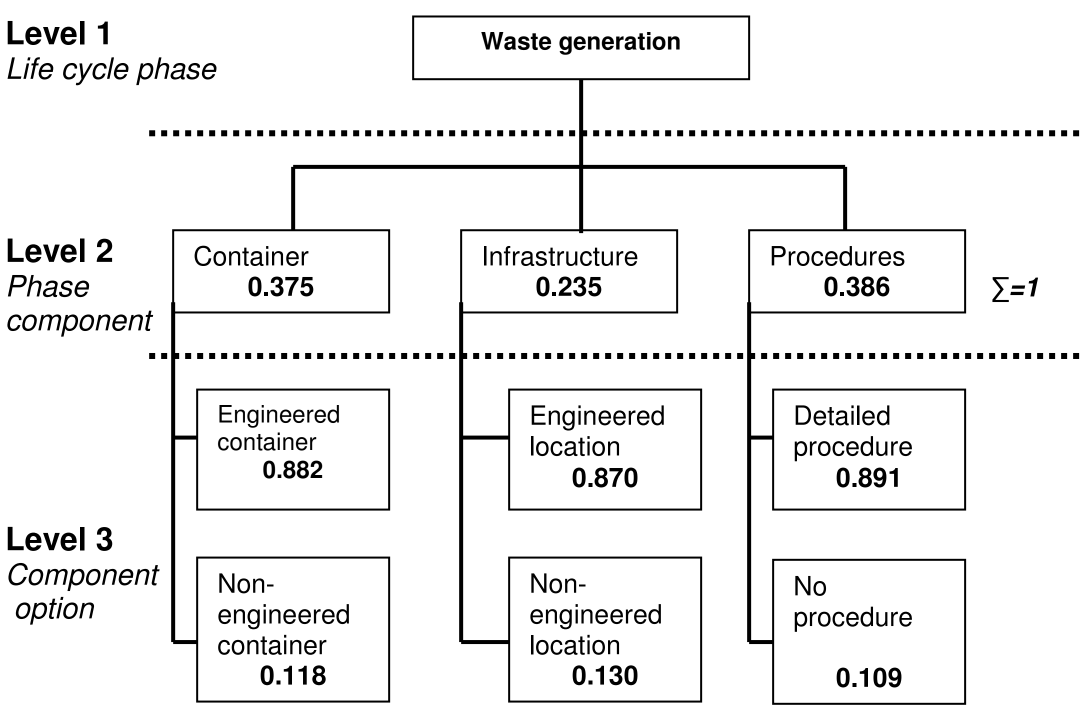

Figure 3.7: Hierarchical tree of available options for waste life cycle generation

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For the engineered container component option the weighted value is:
(0.63) (0.875) = 0.551.

Application of the AHP outcome

Step 6: Computation of options risk factors

Weighting values for options belonging to one phase component are calculated and normalised by assigning to the largest weighting value, a base risk value of 1.0. Equation 3.1 below is then applied to the remaining options. For ease of comparison of the options' risk factors, the reciprocal is taken.

$$R_{ap} = (W_i / N_w)^{-1} \qquad \text{.........equation 3.1}$$

Where: R_{aP} = Risk factor for an alternative in a life cycle phase in relation to the risk factor of 1 for alternative with the least risk for the phase

W_i = Overall weight value for a specific option in a phase component

N_w = Normalization value, i.e. the maximum combined weighting value for the choice of options

Step 7: Computation of alternatives' risk factors

At primary health care clinics HCW is managed by using different combinations of options (scenarios or alternatives). All possible combinations of component options in a life cycle phase are compiled as possible alternatives. A combination has one option belonging to each of the phase components in level 2, e.g. Engineered Container (EC) + Engineered Location (EL)+ Detailed Procedures (DP) for the generation phase. The risk posed by each alternative is related to the alternative with the least risk by adding the weighted values of the options and normalising the result. The reciprocal is again applied to get a risk factor.

Saaty has been criticised for the use of the Eigenvector by Baba e Costa and Vansnick (2001) using the principal eigenvector because they state that it does not always meet all required mathematical condition. Laininen and Hämäläinen (2002) critisize the eigenvector for its lack of practical statistical theory. Although the AHP has been criticised before by Watson and Freeling (1982 and 1983), Belton and Gear (1983 and 1985), French (1988), Holder (1990), Dyer (1990a and b), Barlizai and Golany (1994) and Salo and Hämäläinen (1997), the AHP methodology has not been changed. Harker and Vargas (1987) have discussed these major criticisms and proved with theory and examples that they are not valid. They proved the AHP to be a viable and useful decision-making tool and it has been applied in real life cases as reported by Zahedi (1986), Golden *et al.* (1989), Shim (1989) and Vargas (1990). Laslib and Jinesh (2001) have applied the AHP to environmental management systems while HajShirmohammadi and Wedley (2004) applied the AHP to centralisation/decentralisation strategies.

Correlating AHP and life cycle management terminology

Due to the different terminologies used in the AHP and life cycle management fields, it is necessary to correlate the two terminologies for application in WasteOpt. The use of AHP terms depends on the type of hierarchical tree and its application. Table 3.4 summarises the AHP terminology as used in WasteOpt.

Table 3.4: Correlation of AHP and LCM terminology

Classified hierarchy levels	Conventional AHP terminology	WasteOpt terminology
Level 1	Overall objective or focus.	Essential life cycle phase.
Level 2	Criteria, property, factor, or influence.	Essential life cycle phase components.
Level 3	Alternatives, possibilities, or outcomes.	Life cycle phase component options.

3.3.2 Life Cycle Management

Life Cycle Assessment (LCA) is a tool used to predict the environmental impacts of a product or service (in this case waste) from cradle to grave (SABS ISO 14040). Extensive data of inputs and outputs is required and these are converted into their effects on the environment. LCA has four distinct phases, which are described below (White *et al.*, 1995):

Goal definition: defines options to be compared, the intended use of the results, the functional unit and the system boundaries.

Inventory analysis: accounts for all material and energy inputs and outputs.

Impact analysis: converts the inventory into environmental effects.

Interpretation: balances the importance of different effects.

Due to the reduced availability of data experiences in developing countries situations and the data intensiveness of LCA's, the Streamlined Life Cycle Assessment Approach (SLCA) is proposed, which is life cycle management. It still includes the four stages of the conventional LCA, but with reduced quantitation. The approach uses qualitative rather than quantitative data and the impact analysis procedures are simplified (Rogers *et al.*, 2002). Based on the AHP and the SLCA approach, WasteOpt is developed as described below.

3.4 THE DEVELOPMENT OF WASTEOPT

3.4.1 Goal and scope development

1. Functional unit

The functional unit of WasteOpt is defined as *the amount of health care waste generated in an average rural primary health care facility in one day.* It can be represented as a table and the user can modify the quantity and composition of the HCW in the functional unit.

2. Boundaries of the development work

The setting of the boundary relies on the assumptions made for the system in question. The assumptions used for WasteOpt are as follows:

- HCW is segregated from general waste.
- HCW begins its cycle when medical supplies have served their purpose to become classified as waste (corresponding to the "cradle"). The cycle

ends at final disposal that corresponds to the "grave". Emissions to air, water and soil correspond to the final boundary.

- In terms of temporal dimensions, the system is bounded by the time at which the HCW has caused a predetermined percentage of its impacts (5 %).
- The individual life cycles of the various unit processes are taken into account if they fall within a certain cut-off criteria, e.g. the conventional relative mass energy economic (RMEE) system boundary selection.

3. Allocation assumptions

It may not be realistic to assume that Healthcare Risk Waste (HCRW) is always segregated from Healthcare General Waste (HCGW). If the two types of waste are collected, handled, stored, treated and/or disposed together, the resultant impacts should be allocated to the two types separately. For the purpose of this tool, however, the risks associated with HCGW when contaminated with HCRW are regarded as considerable and thus all impacts are allocated to the HCW in general (HCRW + HCGW =HCW).

3.4.2 Development of an Inventory Analysis Database

WasteOpt allows the population of an inventory using data that is available. The requirement of qualitative or quantitative data depends on the ultimate use of the results of the study: if the aim is for strategic decisions, less data or qualitative data is required. The more the use of results shifts towards design or redesign of systems, then the more quantitative data is required. WasteOpt includes the use of the WHO RAT for collection of data on the current practices of HCWM throughout the life cycle of HCW.

3.4.3 Development of an Impact Analysis Procedure

Potential and actual impacts associated with the inputs and outputs at each stage, are identified. These impacts are classified as follows:

- Quantitative: impacts that are directly measurable and an estimate of its uncertainty can be made, e.g. the cost associated with a certain unit process in the life cycle.
- Qualitative: non-quantitative impacts that can be assigned a risk based on expert assessment.
- Direct: a direct impact on a receptor, e.g. a needle prick on a health worker, which can result in an infection.
- Indirect: an indirect impact on the environment, e.g. dioxin formation by a poorly-operated incinerator.

An impact rating system is availed which uses a linear scale from 1 (lowest risk) to 10 (highest risk). These risk factors are based on calculations from acquired data. They may also be assigned by expert assessment by evaluating the compliance of a practice or equipment to set standards, e.g. SABS code of practice for handling waste from health care facilities.

3.4.4 Development of an Interpretation Procedure

WasteOpt calculates the overall impact of the unit processes in the life cycle of HCW and tallies them into a single score. The lower the final score, the lower the overall risk of that specific option. The different HCWM options in an area are compared and the results are presented graphically according to the following criteria:

Overall risk due to direct exposure of health care workers and the public.

Overall risk due to indirect exposure of health care workers and the public.

Overall costs for implementing and operating the HCWM system.

The overall model process for WasteOpt is diagrammatically presented in Figure 3.8. Figure 3.9 summarises the overall flow of the research process.

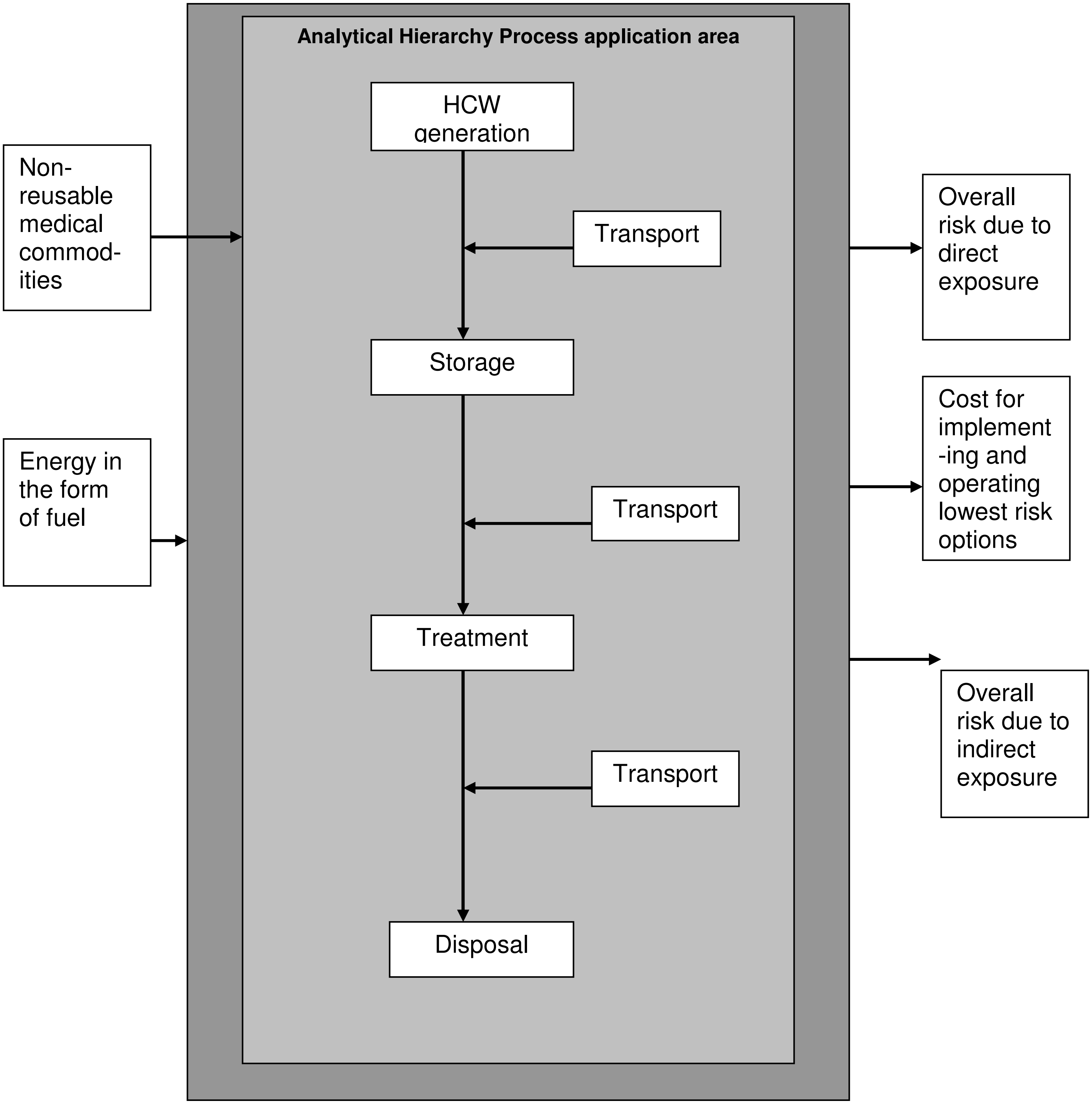


Figure 3.8: The WasteOpt Model summarised

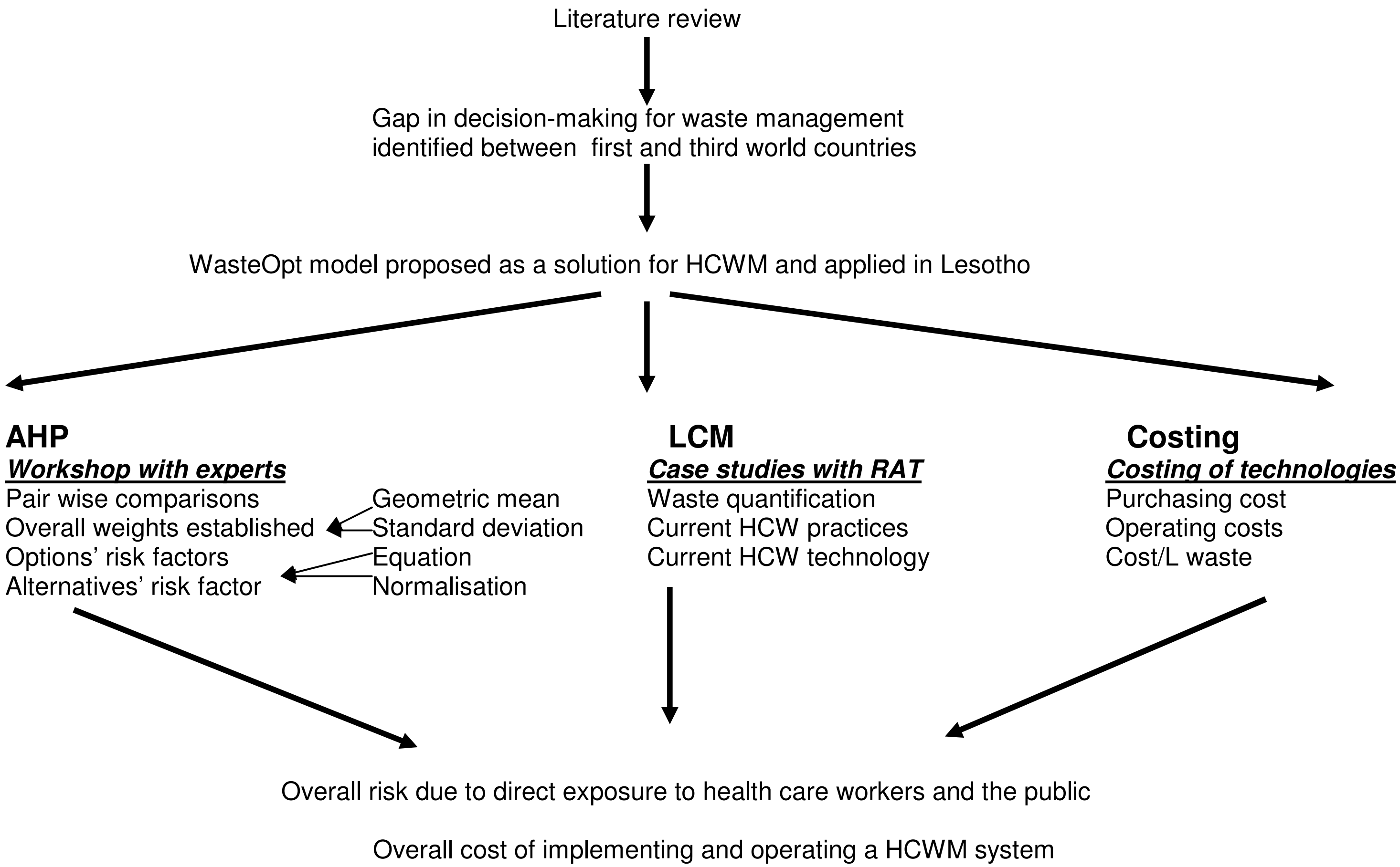


Figure 3.9: The WasteOpt process flow (with AHP, LCM and Costing integration)

CHAPTER 4

Research methodology

1. INTRODUCTION

This research project is directed towards resource-poor decision-makers. It aims to provide them with a practical tool to identify and prioritise options that reduce impacts on the public and health care workers resulting from the management of hazardous waste generated at health care facilities. To achieve this, both qualitative and quantitative primary data was acquired. The data was focussed on the current practices of managing waste from “cradle to grave” in rural health care facilities. It also focussed on weighing available options that can improve the situation.

The research objectives were thus met by completing the following phases:

- Literature review.
- Supervisory waste management pilot study of a rural South African health care facility.
- Case studies of ten (10) rural primary health care facilities in Lesotho.
- Holding a workshop with health care waste experts in Lesotho.
- Risk factors computation and identification of options and alternatives that minimise infection.
- Data analysis and interpretation.
- Conclusion and recommendations.

2. LITERATURE REVIEW

A literature review was conducted in order to find out what research had been done on health care waste, risk assessment and other related aspects. This shed light on what had not been done that could be used to define the scope of the research. The comparison of waste management in developing and developed countries shed light on what gaps need to be filled in developing countries. The studies that have been conducted to this point in Lesotho did not encompass the risk of waste handling and the costs of efficiently managing health care waste. This is what the research aims to address.

The literature was taken from various sources, including official letters from the government of Lesotho to the Council for Scientific and Industrial Research (CSIR) South Africa, books, journals, government documents (Lesotho and South Africa), the World Wide Web and similar studies performed in other countries, among others.

3. PILOT CASE STUDY IN SOUTH AFRICA

A pilot case study was conducted towards the end of 2004. The aim of the supervisory study was to ensure that the researcher would be autonomous in the subsequent case study undertakings in Lesotho and determined the suitability of the WHO RAT (World Health Organisation Rapid Assessment Tool) in achieving the objectives of the research.

Mmametlhake hospital (Nkangala district) was the targeted facility. The main reasons it was specifically chosen were that:

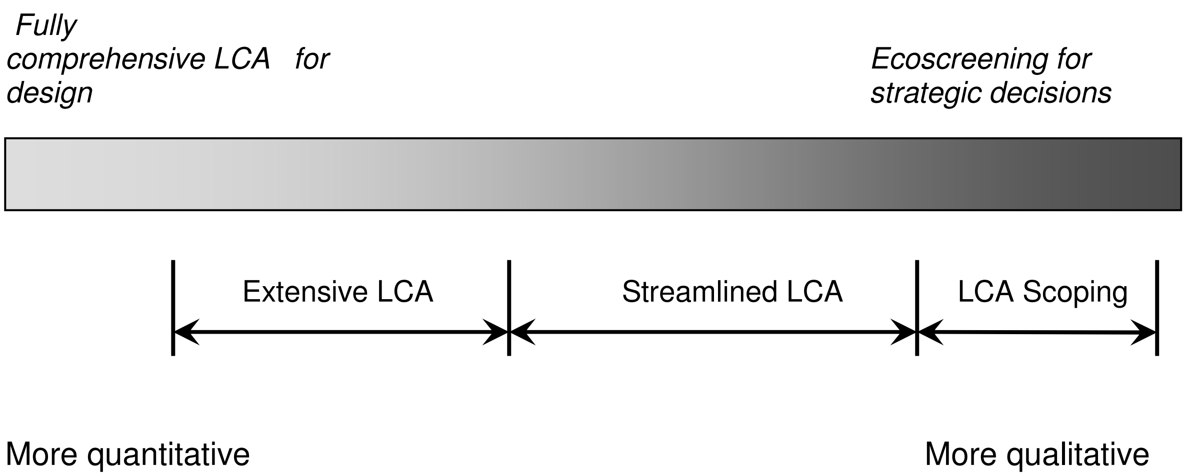
a) Mmametlhake was used as a pilot project for a new specification for a small-scale incinerator designed by specialists at the CSIR. The specific model would be included in options for treatment of HCW in Lesotho. It was worthwhile to consider this incinerator model for rural health care facilities due to its low maintenance and high efficiency.
b) The hospital was geographically convenient (Yin, 1989).
c) The facility was slightly different (in terms of services offered) and was bigger than the real case study facilities. It therefore prepared the researcher for handling large amounts of data.

The RAT was used in its original form to interview relevant staff. A report was compiled afterwards, which was, however, not in the format of the findings presented in this thesis. The report is attached in Appendix 4.

4. DATA COLLECTION

Figure 4.1 below depicts that both qualitative and quantitative data were required since a streamlined life cycle assessment (SLCA) approach was used.

Figure 4.1: The LCA/SLCA continuum



Adopted from Graedel, T (1998) and Rogers et al., (2002)

According to Kibwage (2002) qualitative or descriptive methods tend to be strong in validity but weak in reliability, while quantitative methods are strong in reliability and weak in validity. Flick (1998) views the use of these forms of data as triangulation. He asserts that using both qualitative and quantitative data in one study is a complementary compensation of each method's weaknesses. The use of the two methods thus strikes a balance between the strengths and weaknesses.

The following methods were used to collect the required data:

4.1 Case Studies

The case study approach was adopted as a means of acquiring qualitative data regarding HCW practices in rural clinics. The findings from the cases were used to verify the applicability of the options in WasteOpt in the Lesotho context, as well as to evaluate the potential risk at the different clinics by allocating calculated risk factors to the current HCWM scenarios observed. As Yin (1989) asserts, "*the case study is preferred in examining contemporary events...*" and adding direct observations and systematic interviewing makes case studies more relevant than other strategies like history reporting. Reige (2003) recommends that maximisation of the four tests for establishing quality in qualitative studies, is important. These tests are listed below, together with techniques that were used to maximise them.

1. Construct validity:
   a) The use of verbatim interview transcripts and notes of observations made during the field trips.
   b) Letting key informants review interview scripts after the interviews. As will be discussed in the following section, key informants of a workshop were also given a report during the writing of the research to alter unclear aspects (Yin, 1989).
2. External validation was maximised by defining the scope and boundary of the study during the study design, to achieve generalisation [over the study area] (Reige, 2003).
3. Reliability:
   a) The recording of data mechanically using a camera (photographs).
   b) Recording of data in as concrete a manner as possible by:
      - Recording relevant information even if it was not asked.
      - Recording the exact words of interviewee.
4. Internal validity:
   a) The display of diagrams and illustrations in the data analysis phase helped to build explanations in the data analysis phase.

4.1.1 The Choice of Case Studies

Rural clinics were targeted and the following were chosen using a stratified random sampling. This sampling method was chosen to reduce bias. The stratified random sampling method was coupled with "sampling with replacement". This meant that all the elements were eligible for selection at any stage of the selection process (Tryfos, 1996). It was discovered after the initial identifying of samples that some of the selected clinics were closed, while others had been incorrectly assigned to a stratum, which required that replacements were chosen.

Clinics falling within the Lesotho Flying Doctors Services (LFDS) were excluded from the sample population due to the inaccessibility of the clinics by car. Also clinics situated in urban areas did not form part of the population.

The sample size was chosen such that it represented proprietorship of clinics in the representative ratio of 49 % Christian Health Association of Lesotho (CHAL), 50 % government and 1 % private. Of the ten clinics studied, five (5) were public owned, four (4) were church owned (and therefore coordinated by CHAL), while one (1) was private (belonging to the Red Cross Society) as shown in Table 4.1.

Table 4.1: Clinics selected for case studies

Public Health Centres	CHAL Health Centres	Private Health Centres
Likalaneng	St Leonard	Kolojane
Linots'ing	Matukeng	
Sekameng	St Barnabas	
Matsieng	Holy Cross	
Malealea		

4.1.2 Sources Of Evidence

Questionnaire/interviews: The WHO RAT was used as the questionnaire/interview tool at the ten (10) rural clinics in Lesotho. It comprises both open and close-ended questions. The tool has been tested and used widely in many countries. It was however modified to include more financial management questions for the following reasons:

- The RAT was developed in a developed country (for use in 2nd and 3rd world countries) where financing of HCWM is not a constraint. For a developing country financial evaluation is vital due to lack of funds.
- Some clinics belong to non-profit organisations (NPO's) that are not motivated to earn profit. They must however acquire, manage and allocate funds so that the main mission of the organisation can be realised (Bryce, 1987).
- In any organisation, strategic management and financial function is intricately tied and thus bad or uninformed financial decisions can lead to mission failure.

Health care institutions are tasked with the responsibility for managing their health care waste. This is a completion of the cycle of health care that is not given the attention it deserves, partly due to financial constraints.

- The health care services of Lesotho are delivered by a partnership of government, CHAL and other NPO's. Since health care waste management will be compared by proprietorship, government clinics are at a financial advantage because they can exist forever under the taxing power of the state, despite the strength of their financial management status. Since other NPO's have no such powers, they may lack funds to implement waste management targets, go bankrupt and close (Bryce 1987).

The RAT touches on financial issues and as such does not cover all the important factors of good financial management. These important factors include, among others, budgeting, sustainability of funding and the cost for implementing and operating appropriate health care waste management systems. By the evaluation of such questions personnel can understand the cause for their deficit in allocations for health care waste management in their plans. It also helps them to recognise that appropriate HCWM is part of health care provision. The

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decisions of the planner should also focus on the protection of health workers and the public through environmentally sound practices.

The modified questionnaire also enables the capturing of qualitative data (current practices and infrastructure) and quantitative data in the form of amounts of waste generated by the clinics. The modified questionnaire is included in the thesis in Appendix 3.

Direct observations: These were done in the field visits to the clinics. These were recorded exactly as observed. Photographs of the main observations were also taken.

Records: The following data were acquired from records.

a) Budgets (as organisational records).
b) Patients served per day and injections given over a certain period (as service records) (Yin, 1989).

4.2 The Workshop

A two-day workshop was conducted for experts in waste management in Lesotho. The objectives of the workshop were:

a) to establish weighting values for the waste management options at primary health care facilities in Lesotho;
b) to establish the objectives and the roles of each participant in the waste management system of Lesotho;
c) to reach a consensus regarding the definitions of HCW and a Primary Health Care (PHC) facility; and
d) to identify the gaps within the HCWM system of Lesotho and devise a way forward for filling the gaps.

4.2.1 Selection of the Panel of Experts

Noble (2003) is of the opinion that the size of an assessment panel depends on the objectives of the assessment, resources and time available. As few as 10

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people are sufficient. This panel should comprise of stakeholders, facilitators and experts. The workshop had a maximum of 18 participants. Due to time constraints, two stakeholders from the private sector could not attend. There were 15 participants from the Ministry of Health and Social Welfare (national and district levels), Ministry of Tourism, Environment and Culture, CHAL, Department of Environmental Affairs and Tourism (SA), as well as three facilitators from the University of Pretoria and the CSIR. The criteria for selecting the panel and the number who participated per category are shown in Table 4.2(a) (Noble, 2003). It is based on the recent involvement of participants in waste management.

Table 4.2(a): Selection by recent participation in health care waste management

Selection criteria	Number of participants
Experience in two or more fields	5
Current or previous leadership	8
Experience in affected field	2
Experience in education and profession	5
Experience in similar assessments	5
Professional publications	2
Participation in professional meetings	18
Membership to HCWM panels	18
Interest in the HCWM	1

Saaty (1986) and Noble (2003) advise the engagement of a small group of participants to attain a sharp focus. The panel of experts was representative in number but deficient in public-private significance since only one participant represented non-governmental organisations (CHAL). Saaty (1980) also states that the level of expertise need not be equal as long as all participants are familiar with the problem.

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Table 4.2 (b) represents the classification that was used to cluster the participants within the workshop to analyse and classify the Analytical Hierarchy Process consistency of the participants.

Table 4.2(b): Grouping by function in organisation

Focus area	Group	Level of operation	Number of participants
Health inspectors	HI	Implementation	6
Occupational health	OH	Strategic planning	1
Environment officers	EO	Strategic planning	2
Infection control	IC	Planning	2
Technical officer	TO	Strategy and implementation	2
Senior health inspectors	SHI	Strategic planning	2

The information above is based on representation of waste managers (especially health care waste) from one private and two public organisations in Lesotho. The criteria for grouping were the level of operation of participants in their respective organisations and the major focus areas.

4.2.2 Sources of Information

Presentations: This activity was done both by participants and facilitators of the workshop. The facilitators used presentations to inform the panel of the research, its objectives and expected outcomes. The panel was also introduced to the AHP. Participants gave presentations on their roles in HCWM in a separate session described below.

Colour coded cards: Participants were asked to write down the roles they play within the following categories: Policy, Action Plan, Standards, Monitoring, Capacity-building and Tenders. The participants were given colour-coded cards to write on.

Pink: Name and position

Green: The role that he/she plays in waste management

Yellow: The challenges that he/she faces in his/ her position

The outcome of this exercise is tabulated in the findings.

Open discussions: Throughout the workshop, participants were advised to ask questions, which were answered by both the facilitators and the panel. This encouraged openness and transparency in the current situation of HCWM. The questions, answers and comments emanating from the different sessions of the workshop are presented in the findings.

Consensus: Definitions for the issues mentioned below were reached by consensus. The nominal group technique was engaged for these sessions to reach a common understanding for thee whole group.

a) Statement of the HCWM problem.
b) Solutions to the identified problem.
c) The objectives of Lesotho's waste management system.
d) The definition of HCW in the Lesotho context.
e) The definition of a rural primary health care facility.

Although Coxon (1982) argues that "*aggregating assessment data without examining individual differences may lead to a false sense of group consensus*", Noble (2003) argues that the aggregate of a group will provide results that are superior to those of an individual.

AHP questionnaire: The hierarchical trees were constructed prior to the workshop. The trees were presented on flip charts when doing the comparisons for each life cycle phase. Saaty (1986) recommends that two session leaders and an assistant are used, and this procedure was followed.

The questionnaires for the South African case (with options relevant and/or available in South Africa) were evaluated by the panel and modified so that the options suited the Lesotho context. The changes are discussed in Chapter 5. A

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computer terminal was also set up to consolidate the results as they were generated. It also helped the facilitators to spot inconsistency in the comparisons. The facilitators were able to highlight the consistencies of the weighting factors during the workshop, and this was useful to improve individual consistency.

Planning: The group proposed the way forward by specifying how they wanted to improve HCWM and what they needed to make it happen. The planning session was completed after allowing each individual to raise goals and activities that they believed needed to be performed in order to reach the goals. All these were combined into a report of the workshop (Appendix 2).

4.3 Expert Consultations

Expert e-mail consultation sessions were held with the senior technical officer of CHAL. The expert provided costing information on approximations of infrastructure construction in Lesotho. The approximations included the purchase of materials and labour, but excluded transportation cost.

4.4 Technology Costing

4.4.1 Quotations

The following companies were contacted and provided quotations for the listed technologies (details of contacts in appendix 8):

Reco: refrigerated storage room

Saubtech: Multi- and single-chamber incinerators

Wastegroup: waste containers

The cost of transportation options were obtained from the following sources:

Vehicles: Ministry of Health and Social Welfare, National Healthcare Waste Management Plans (draft).

Trolleys: www.nwims.co.za. The listed costs were inflated by a 10 % contingency for each year following the "last updated" date on the website.

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5. DATA ANALYSIS

5.1 Quantitative Data

Quantitative data resulted from the application of the AHP (analytical hierarchy process) by participants and from waste generation rates in the case studies.

- These comparison (weighting) values from the AHP were populated into Excel spreadsheets to determine their consistency, using Saaty's fourth method (Saaty, 1980) of matrix regression. The comparison values were used for calculations of risk factors per option and alternatives. The results of the calculations were normalised (divided by the largest value element) to yield meaningful comparisons among the elements. The reciprocal was taken to enhance comparability of the risk factor with the common understanding of risk, i.e. risk increases as preference reduces.
- Standard deviation was used because it is the most important measure of variance (Steyn *et al.*, 1994). The geometric mean method of aggregation was used to dampen the influence of outliers (Aull-Hyde *et al.*, 2004). Variability would also assist in judging our reliability on the mean (central location) as a representative of the data.
- The resultant risk factors were classified into three categories, namely lower risk (1.0-1.9), medium risk (2.0-4.9) and high risk (5.0 and higher).
- Some qualitative information was converted to quantitative. Percentages were used to depict the findings at case studies. The percentages were for:
  - Types of containers used
  - Clinics that practice waste segregation
  - Trained waste handlers

5.2 Qualitative Data

To verify the quantitative outputs of the AHP, the following methods were used to analyse the data.

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- Analysis of the prevailing situation at the time of the visits was performed per phase. The major findings were classified into procedures, technology, containers, infrastructure and transportation methods.
- The risks posed to health care workers in the clinics visited, were also determined by applying the relevant calculated alternatives' risk.

6. LIMITATIONS TO THE METHODOLOGY

6.1 Analytical Hierarchy Process Limitations

The main limitations observed in the AHP application are:

a) There was a lack of understanding of the ranking procedure.
b) There was lack of full information on HCWM systems at the workshop.

6.2 Case Study Limitations

a) According to Yin (1989): "*A...common concern about case studies is that they provide very little basis for scientific generalization*." Ten cases were studied out of a total of 172. Whether generalisation is applicable will be discerned in the discussion of the results.
b) Bias may have prevailed for certain sections of the case studies since the researcher went to the field with prior knowledge of what to expect in rural clinics of a developing country. Methods of reliability and validity testing were discussed earlier that eliminate the bias.
c) The sample size for case studies was limited as a way of reducing the time it would take to study the statistically required sample size.

7. PROBLEMS ENCOUNTERED

7.1 Case Studies

a) Some clinics did not have a balance to weigh the waste generated. The waste generation was therefore estimated in litres throughout the field survey for standardisation.

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b) Some clinics did not segregate their waste such that sharps and soft waste were mixed in an unlined bin. The risk of transferring such waste to a container of known capacity was high and had to be avoided. In order to estimate the waste generated, the waste was estimated in the holding container.

c) In some clinics, due to understaffing and large numbers of patients seen, the time allocated for the case was unsatisfactory.

d) No clinic was able to give information of what it had cost to erect current waste management technologies or how much was spent to operate these technologies per unit of waste.

7.2 Workshop

a) One participant attended the workshop for only half of the first day, while another one attended for one day only. Two other participants attended only for the second day. Their sets of results were therefore incomplete and could not be used.

b) In preparation for the workshop, not all HCWM technology options were identified and included in the ranking. Some that were identified were excluded by consensus since they have never been used in Lesotho.

c) Some of the participants could not understand the meaning of inconsistency and could not be urged to alter their results to an acceptable level.

d) There were differing levels of participation in the workshop (managers and implementers). The implementers (district level) were ready to acquire new knowledge on management systems while the national managers debated new knowledge at a higher level since they had existing knowledge on waste management systems.

e) The implementers were found to be “black and white” thinkers while the national waste management experts perceived “grey” areas.

f) The application of the AHP was taken as a judgement call to many, whereas it is a ranking methodology to assist judgement. Therefore, most participants executed only horizontal and not both vertical and horizontal ranking (See AHP questionnaire, appendix 8). Some participants from the MoTEC saw two discrete sets of values in a criterion.

g) Some of the participants performed the ranking with pre-conceived ideas, which clouded their ranking abilities. It was their perception that direct weighting was easier and more relevant than pair-wise comparisons.

h) While some members thought the scale was too small (1 up to 9) and disabled them to allocate numbers properly, other participants were confused by the scale such that they mixed the left and the right hand sides of the scale when allocating.

i) Imprecision: Comparisons could not be guaranteed to have high precision.

j) There was a temptation to conclude prematurely from small amounts of data available (AHP results) whereas qualitative data was also required.

The limitations and problems encountered compromised the quality of this study to an extent. The goals of the study were realised despite these setbacks due to the sturdiness of the tools applied in the study. The results are stipulated in the following chapter.

CHAPTER 5

Results and discussion

The application of the methodology elaborated in Chapter 4 lead to the collection of qualitative and quantitative data. This chapter consolidates all the data and discusses the highlights of the research, which are the Analytical Hierarchy Process (AHP) results and the current practices of health care waste management (HCWM) in rural clinics. Analysis of the AHP results per life-cycle phase was performed, after which the results were applied to the case study clinics. The costs for all technologies discussed are tabled at the end of the chapter. An insert of the life- cycle of health care waste is placed at the beginning of a subtopic to show the reader where s/he is. In order to distinguish between the hierarchical levels the following formatting will be used:
Life cycle phase in *italics*, Components in underlining and Options in **bold**.

5.1 CHANGES MADE IN THE WORKSHOP QUESTIONNAIRE

From section 4.2.2, participants of the workshop were allowed to make changes to the AHP questionnaire by consensus. The group of participants subsequently made the following changes:

Options for *on-site disposal* activity

1. The comparison of transport options was removed due to the argument that at the disposal site no transportation takes place. The transport options for the treatment activity apply for the disposal activity as well.
2. A pit latrine was considered to be a form of a controlled dump.

Options for *central treatment* activity

1. Comparisons were made between **multi-chamber incinerator** (MCI) and **single chamber incinerator** (SCI) only. The consensus was reached by the group of experts and was justified by the fact that all the other methods are not in the future plans for the country and have never been applied.

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Encapsulation was excluded because it was regarded as a stabilization method, which brought no change to the composition of the waste.

5.2 AHP RESULTS

From the first round of questionnaire completion, it was observed that individual consistency decreases as the size of the matrix increases. Consistency was also found to increase as participants worked in groups. The group of health inspectors was the most consistent group while the group of environment officers was the least.

Some of the participants' results were not used in the calculations due to the fact that:

- they were not present on both days of the workshop (IC 2, SHI 2 and SHI 3) and thus their data sets were incomplete.
- some of their single comparison consistency ratios (CRs were more than 10 %. These individual outcomes were not used in the risk calculations of that phase.

Individual consistency was the highest in the generation phase (a CR value of 0.00 for six of the eleven participants). From the classification in Table 4.2 (b) the health inspectors were the most consistent (HI 2, HI 3 and HI 5). This group worked together to agree on an issue before recording results. The two technical officers (TO) were also generally consistent. In five of the six life-cycle phases one of the TO's had a CR below the group's average CR. Since these participants were not working as a team, it is assumed they understood the AHP.

Table 5.1 below summarises the average group consistency and standard deviation.

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Table 5.7: Group consistency and variance

Life-cycle phase	Group average consistency ratio	Group standard deviation
Generation	0.004	0.008
Collection and storage	0.035	0.017
On-site treatment	0.026	0.010
On-site disposal	0.011	0.007
Off-site treatment	0.012	0.011
Off-site disposal	0.021	0.009

The lowest group average value of 0.004 was from the generation phase. It was found to be the easiest phase because three-quarters of the AHP matrices were 2X2 matrices, which are the easiest to deal with and naturally consistent. *Collection and storage* had the highest average since this phase consists of a 4X 4 matrix, which is more difficult (than 2X2 and 3X3) to deal with consistently by the participants. Of the seven matrices of this phase, four were 3X3 and thus the consistency ratio increased. The overall group average consistency for all the phases was 0.018. The data is thus robust to use for further analysis.

Standard deviation was deemed the best method for measuring dispersion around the mean. The phase that exhibited the largest standard deviation was *Collection and storage* due to the varying consistency per matrix size. This can also be attributed to the presence of an outlier in the data set (IC 1), which increased the deviation. *On-site disposal* resulted in the smallest standard deviation due to the majority of matrices being 2X2. The individual and group standard deviation values were closer to the mean.

The results of the AHP are attached in Appendix 1.

5.3 AHP APPLICATION

The risk posed by different options in HCWM or the whole life-cycle is represented in Table 5.2. The figures have been normalized.

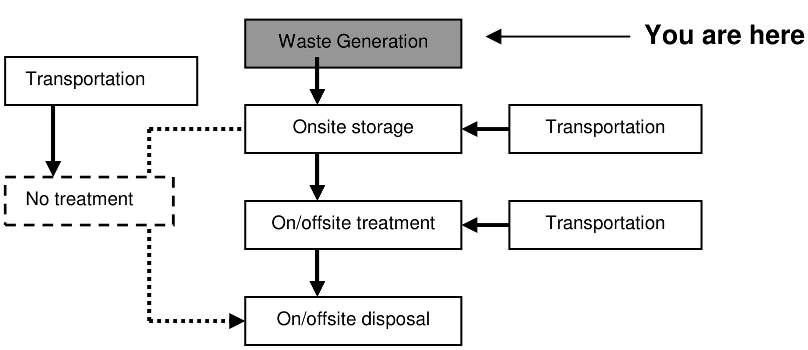
Table 5.2: Calculated risk factors for the choice of options in each component of the life-cycle phases

Life-cycle phase	Component	Options	Risk factor
Generation	Container	EC	**1.0**
		nEC	**7.6**
	Infrastructure	EL	**1.0**
		nEL	**7.0**
	Procedures	DP	**1.0**
		nP	**8.2**
Collection and storage	Aggregation	EC>EC	**1.0**
		EC>nEC	**2.6**
		nEC>EC	**2.6**
		nEC>nEC	**4.3**
	Transport	EW	**1.0**
		EnW	**2.7**
		nEnW	**8.0**
	Container	EC	**1.0**
		nEC	**8.8**
	Infrastructure	REF	**1.0**
		nREF	**3.0**
		nRnEF	**10.3**
	Procedures	DP	**1.0**
		nP	**7.7**
On-site treatment	Technology	SASSI-E	**1.0**
		SASSI-M	**2.7**
		OAB	**11.4**
	Transport	EWT	**1.0**
		GT	**4.2**
		IT	**9.3**
	Container	EC	**1.0**
		nEC	**7.4**
	Infrastructure	ES	**1.0**
		nES	**7.2**
	Procedures	DP	**1.0**
		nP	**7.8**
On-site disposal	Technology	EP	**1.0**
		CD	**4.0**
		OD	**8.8**
	Container	EC	**1.0**
		nEC	**3.9**
	Procedures	DP	**1.0**
		nP	**7.6**
Off-site (central) treatment	Technology	MCI	**1.0**
		SCI	**6.2**
	Transport	EWV	**1.0**

		GV	**4.7**
		IV	**10.4**
	Container	EC	**1.0**
		nEC	**8.6**
	Infrastructure	ES	**1.0**
		nES	**8.3**
	Procedures	DP	**1.0**
		nP	**8.6**
Off-site (central) disposal	Technology	LF	**1.0**
		CD	**3.0**
		OD	**10.2**
	Transport	EWV	**1.0**
		GV	**5.0**
		IV	**12.0**
	Container	EC	**1.0**
		nEC	**8.3**
	Procedures	DP	**1.0**
		nP	**8.1**

The option that posed the most risk differed per life-cycle phase. The most frequently identified options with the maximum risk were the type of transport and technology used. The largest risk was posed by the use of **inappropriate vehicle** in the transportation of wastes to a central location (risk is 12.0). The use of **non-engineered containers** and the location (storage) did not pose maximal risk. The most common scenario was the use of these options in combinations (alternatives in this study). The overall risk is additive and the contribution of each option in an alternative are discussed in the following sections.

4.3.1. Generation



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A general profile of the risk factors was plotted against the alternatives. The non-linear result is shown in Figure 5.1.

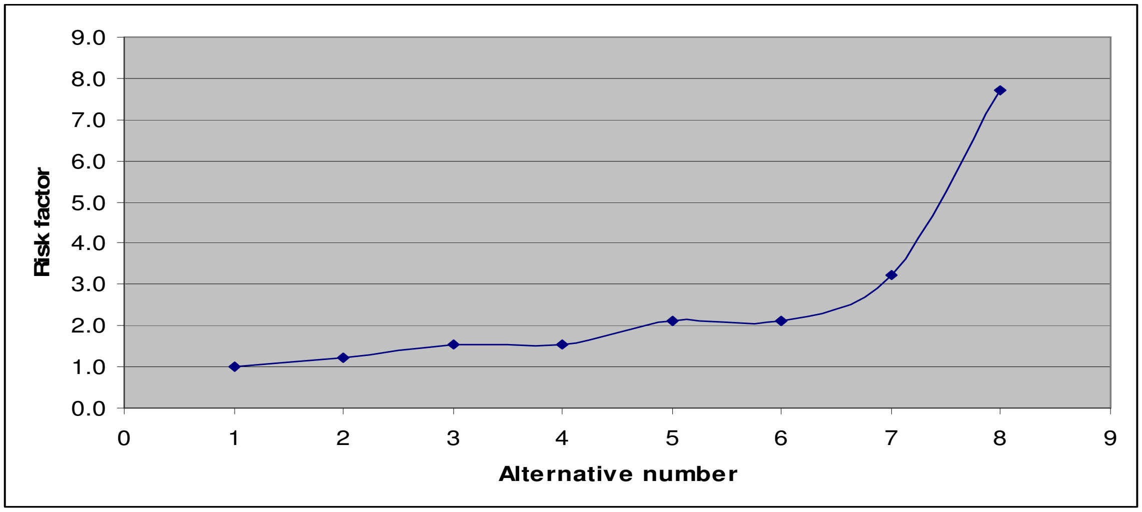


Figure 5.1: Alternative-risk profile for the generation phase

The above mean profile was obtained by sorting the risk factors in ascending order. It illustrates the non-linearity of the data. The most preferred (optimum) alternative (EC + EL + DP) has the minimum risk factor. The more options changes made on the optimum alternative, the more the risk factor increases. Due to the non-linearity, making 50 % changes to the optimum alternative does not increase the risk by 50 %. A single change to the optimum alternative yields a 20 %-50 % increase in risk factor while two changes give a 110 %-220 % increase. A significant increase in risk is observed when DP is changed to nP and EC changed to nEC. Containers and procedures need to be the first priority for the decision-maker. The profiles for the other life-cycle phases are attached in Appendix 7.

The calculated risk factors of the combinations of **engineered location** and **non-engineered location** with the other phase-component options, or grouped alternatives for the life-cycle phase, are shown in Figure 5.2(a).

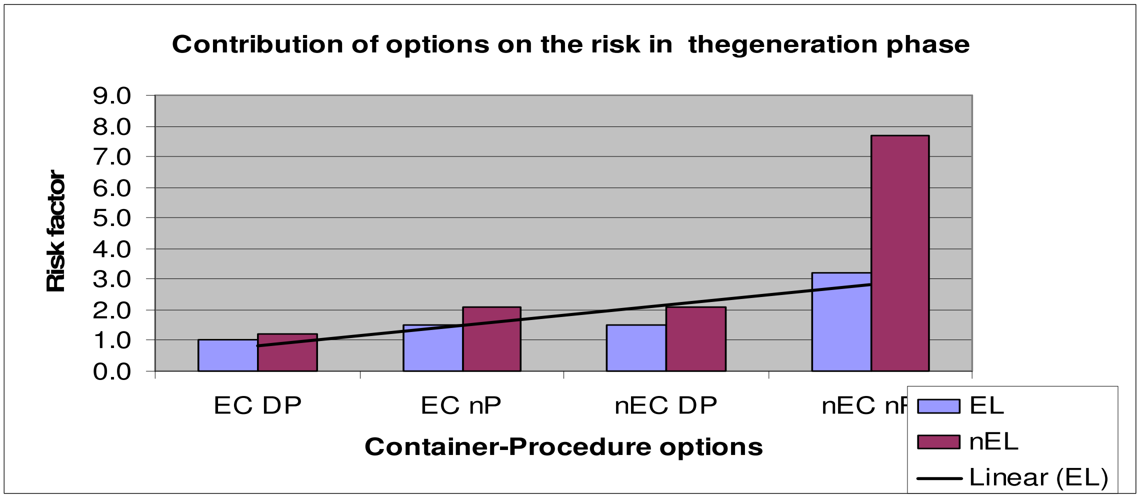


Figure 5.2(a): Graph of risk factors of container-procedure combinations with engineered location and non-engineered location options

The figure indicates that risk increases with the use of non-engineered options coupled with lack of procedures. Non-engineered location of containers during generation increases the risk of infection by waste. The presence of an **engineered container** and **detailed procedures** lowers risk. A **non-engineered location** increases the risk by 20 %. The use of an **engineered location** decreases risk by 40% when an **engineered container** is used without procedures or when a **non-engineered container** is used with **detailed procedures.**

The largest risk in this phase is posed by the use of a **non-engineered** container with no procedures (risk value=7.7 compared to 1.0 for **engineered container** plus **detailed procedures**). For this largest value, a **non-engineered location** increase the risk by 140 % compared to the use of an **engineered location**.

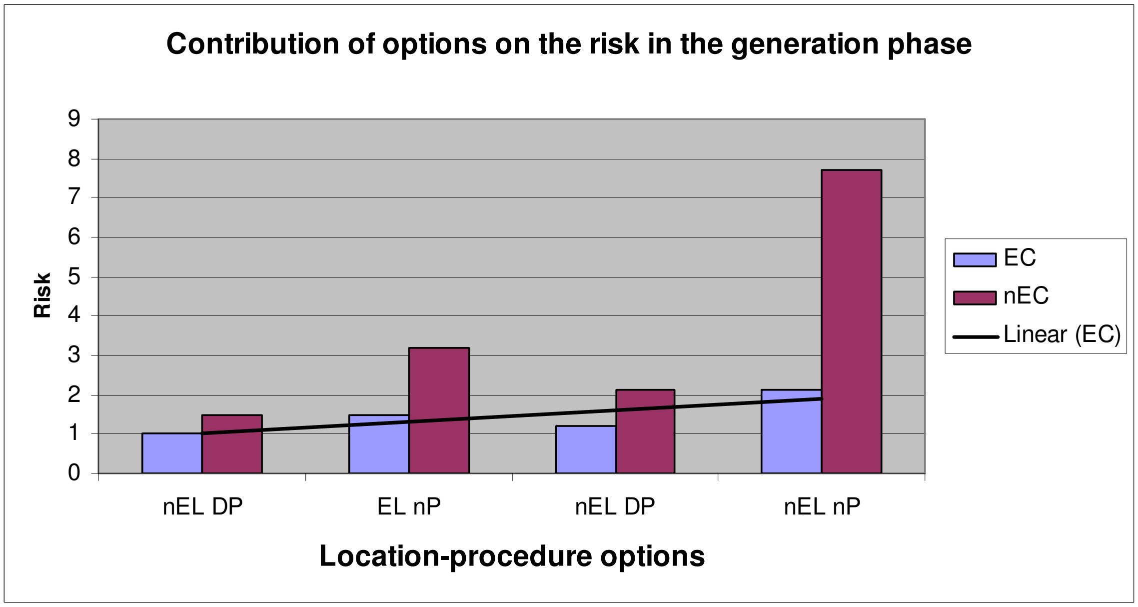
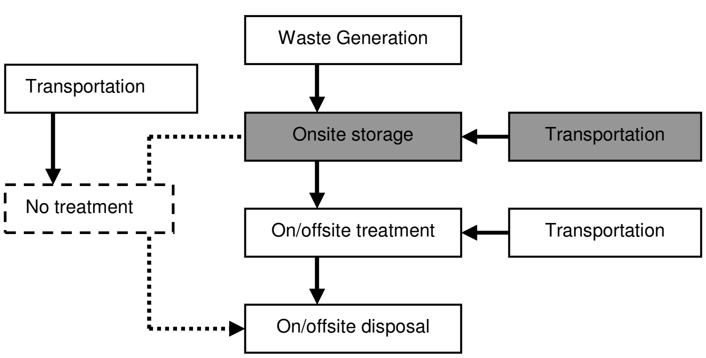


Figure 5.2(b): Graph of risk factors of location-procedure combinations with engineered container and non-engineered container options

From the gradients of the trend lines in Figures 5.2(a) and 5.2(b), **engineered containers** reduce risk more than **engineered location** (gradients of 0.3 for EC and 0.66 for EL).

In general, the most important consideration for reducing risk in this phase is the use of **engineered containers** followed by **detailed procedures**. The location of waste containers is secondary to these two. If there is either an **engineered container** or **detailed procedures**, the location makes little difference.

5.3.2 Collection and Storage



Alternatives were plotted with the four aggregation types against each other below. The risk factors to the different alternatives are as shown in Appendix 4.

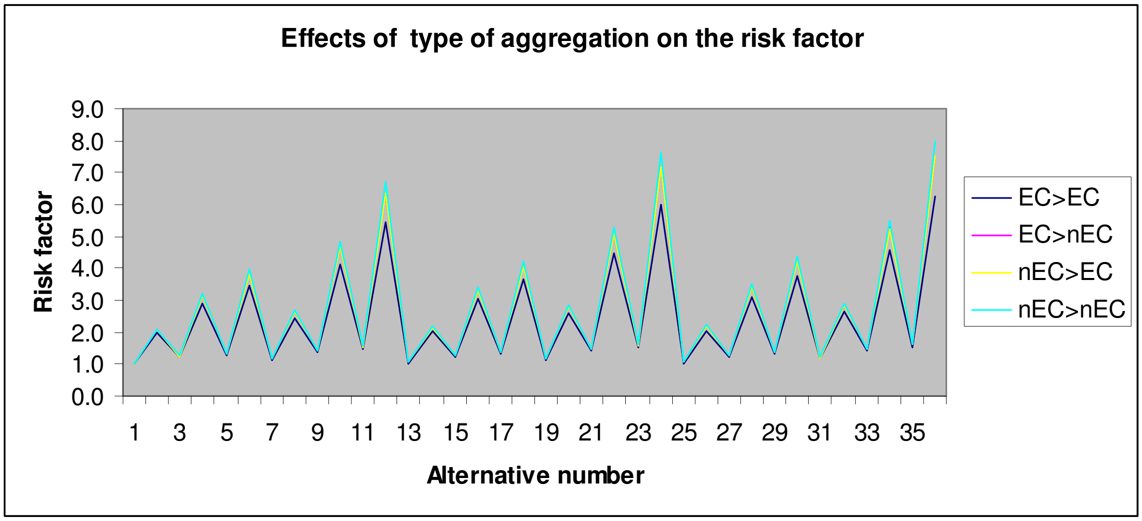
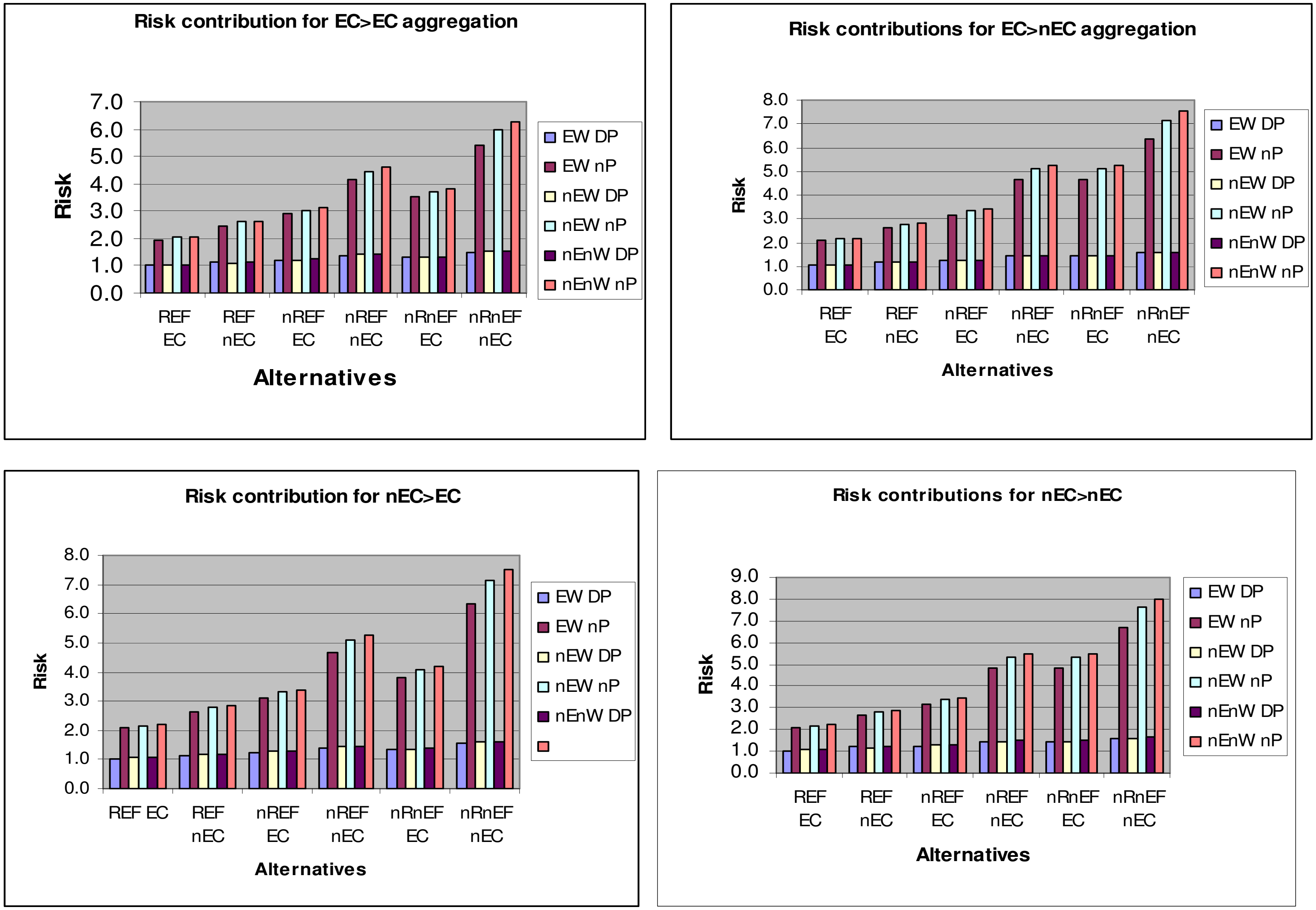


Figure 5.3: The effect of aggregation type on the risk factor for different alternatives

The risk value of 1.0 is obtained for all alternatives with the options set: **detailed procedure, refrigerated storage, engineered wheeled transport and engineered container**, although the aggregation methods vary. All the points at the bottom of the peaks are for alternatives that include **detailed procedures** and therefore reduce the risk of infection during collection and storage. The line representing the transfer of waste from an **engineered** to a **non-engineered container (EC>nEC)** exactly matches the one for **non-engineered to engineered container (nEC>EC)**. This implies that the risk is equal when using nEC>EC and EC>nEC. Generally the type of aggregation changes the risk posed by between 0 % and 20 %, the maximum being from **non-engineered** to **non-engineered containers** aggregation (nEC>nEC).

Figure 5.4(a) to (d) were plotted using factors containing temperature (refrigeration) and container options. The figure represents the four aggregation options.



Figures 5.4(a)-(d): Risk contribution for aggregation method

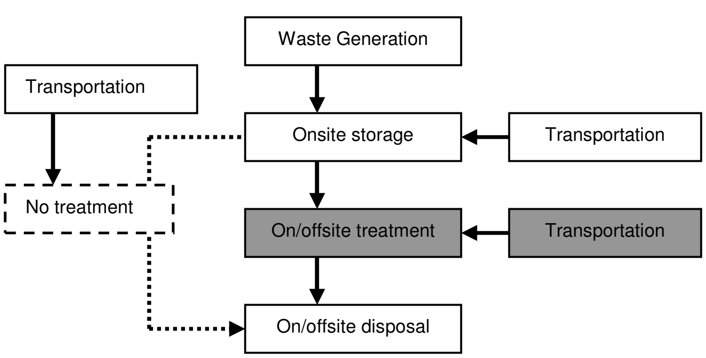
Overall analysis

The figures illustrate that risk increases from **refrigerated engineered** facility (REF), through **non-refrigerated engineered** facility (nREF) to **non-engineered non-refrigerated** facility (nRnEF). All alternatives that contain **detailed procedures** have a lower risk than their counterparts without detailed procedures. Thus three alternatives that contribute most to the risk are EW nP, nEW nP and nEnW nP. **Non-engineered non-wheeled transport** (nEnW) increases the risk more than **non-engineered wheeled** and **engineered wheeled** in succession.

In all plots the risk factors of **non-refrigerated non-engineered** facility (nRnEF), **engineered container** (EC) reduces risk more than the alternative **non-refrigerated engineered** (nREF) nEC. This depicts the importance of the container over that of the temperature of the storage facility.

In summary, the most important consideration to minimise risks in this life-cycle phase is the adoption of **detailed procedures**, followed by the choice of an **engineered transport** (not necessarily wheeled) and **engineered containers**. The choices of the storage facility or aggregation methods are of less concern.

5.3.3 On-Site Treatment



To deduce the changes in risks posed by the *on-site treatment* option, Figure 5.5 was plotted by category of treatment option.

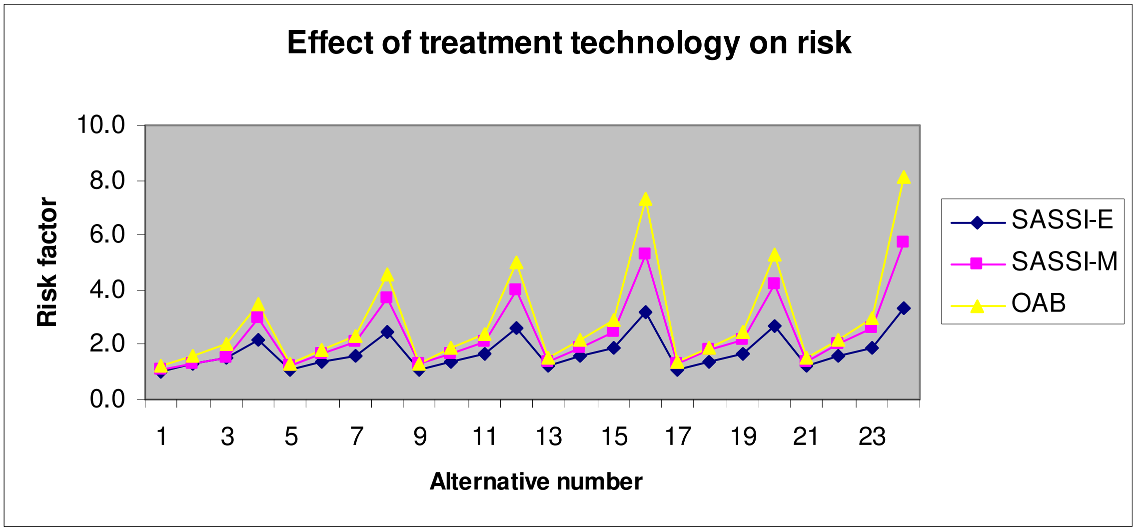


Figure 5.5: Effects of technology variation on risk

From the diagram, all alternatives containing the option of **open air burning** (OAB) pose the greatest risk compared to incineration. Alternatives with the **South African Small Scale Incinerator-Engineered** (SASSI-E) pose the lowest risk of infection. The steep gradients depict the drastic change resulting from the presence of **detailed procedures** and the absence of such. The first gradient of the peak show that as more non-engineered options are included in the alternative, the risk increases.

Figure 5.6 was plotted by holding treatment technology and transportation options constant in order to depict the contribution of the other options.

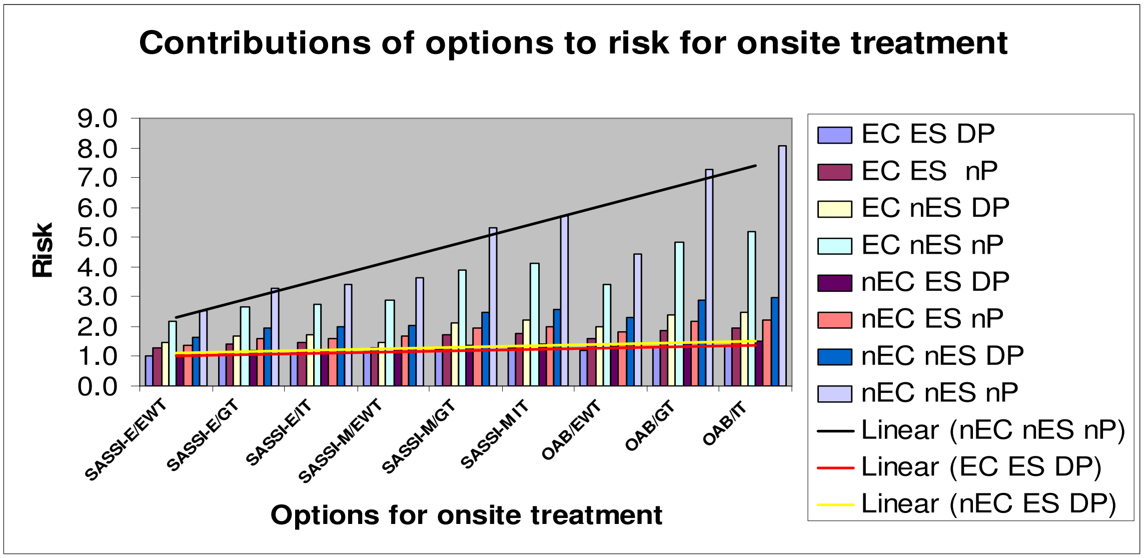
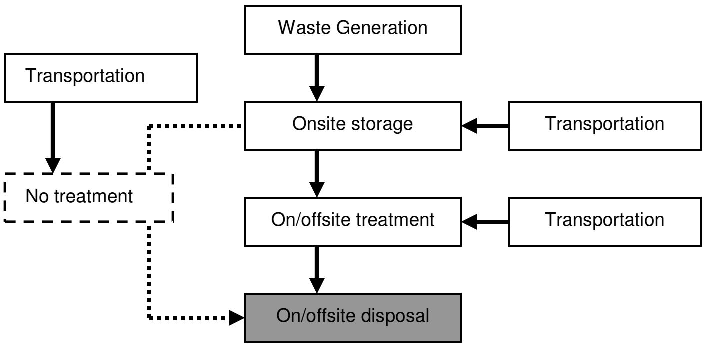


Figure 5.6: Contributions of options to risk for on-site treatment

In agreement with Figure 5.6 above, risk is observed to increase with the transition from **SASSI-E** to **OAB**. The combination that proves to reduce risk to the minimum is **SASSI-E/engineered wheeled transport** coupled with **engineered container, engineered storage** and **detailed procedures**. The largest contribution to the risk factor is the combination of **non-engineered container**, **non-engineered storage** and **no procedures**. As shown by the gradients of the trend lines, risk increases faster when **non-engineered storage**, **non-engineered containers** and **no procedures** (gradient 0.637) are included in an alternative. Risk increases less significantly when the alternative has **non-engineered container, engineered storage** and **detailed procedures** (gradient 0.051). Inclusion of **non-engineered storage, engineered container** and **detailed procedures** increases risk more than **EC, ES,** and **DP**. This gives evidence that **nES** increases risk more than **nEC**.

In summary, for this life-cycle phase, the most important consideration to minimise health risks is to choose **detailed procedures** and an engineered incineration technology, followed by an engineered storage location and lastly by the choice of container.

5.3.4 On-Site Disposal



The alternative versus risk chart was plotted as presented in Figure 5.7.

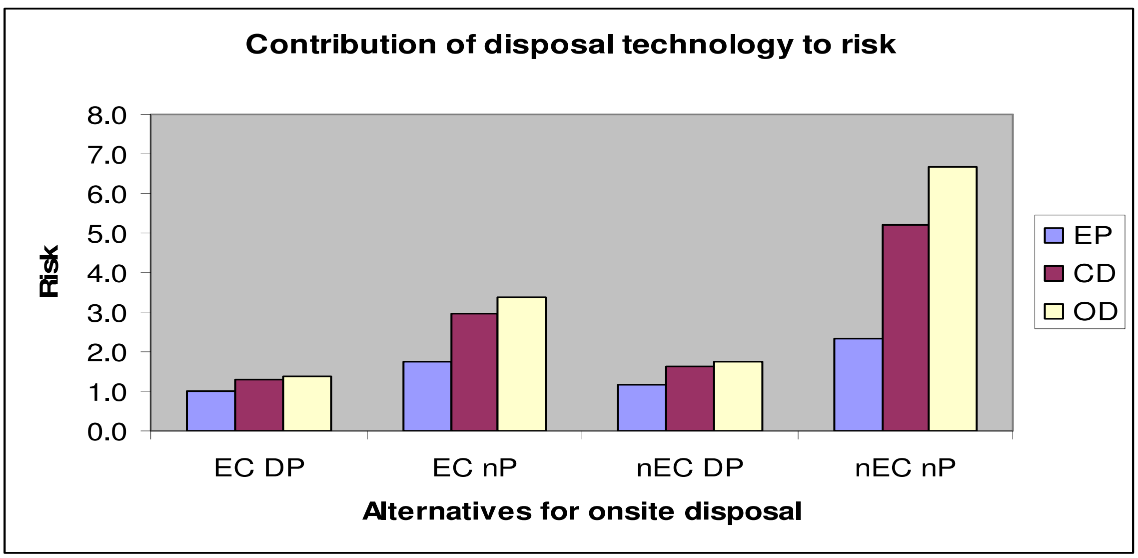


Figure 5.7: Contribution of disposal technology to risk

The trend shown in Figure 5.7 is the increase in risk as a transition is made from using an **engineered pit** (EP) to **open dumping** (OD). An **open dump** is 8.9 times riskier than an engineered pit. The coupling of **OD, CD** and **EP** with **engineered containers** (EC) and **detailed procedures** reduces the risk considerably from coupling them with **no procedures** and the use of **non-engineered containers** (nEC). An interesting observation is the fact that procedures are more important in risk reduction than containers. The choice of **nEC, DP** reduces risk more than **EC, nP**. It is important that whichever *on-site disposal* method is chosen should be accompanied by **detailed procedures** for its use. This is also depicted by the risk factor of 1.0 for **EP, EC, DP** and a risk of 1.2 for **EP, nEC, DP**. The absence of procedures doubles the risk to 2.4 for the latter (which is **EP, nEC, nP**). From Table 5.2 the individual risk factors are as follows: CD=4.1, OD=8.9, EC=1.0 and nEC=3.9; it is clear that the disposal technology is more important in reducing risk than containers

The reduction of risk posed by health care waste in this life-cycle phase can be achieved by considering, most importantly, the selection of **detailed procedures** followed by engineered disposal technology and **engineered containers**.

5.3.5 Off-Site (Central) Treatment

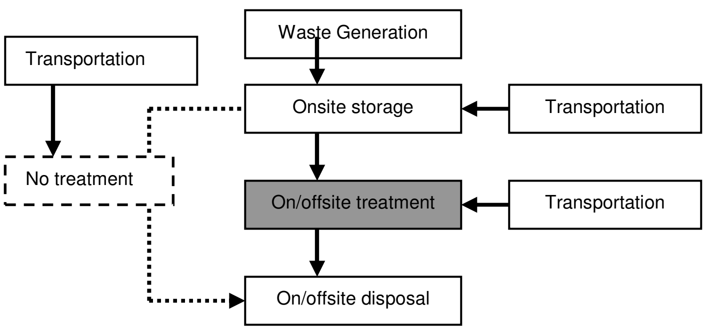


Figure 5.8(a) is the result of calculations in which treatment technology and transport options were kept constant

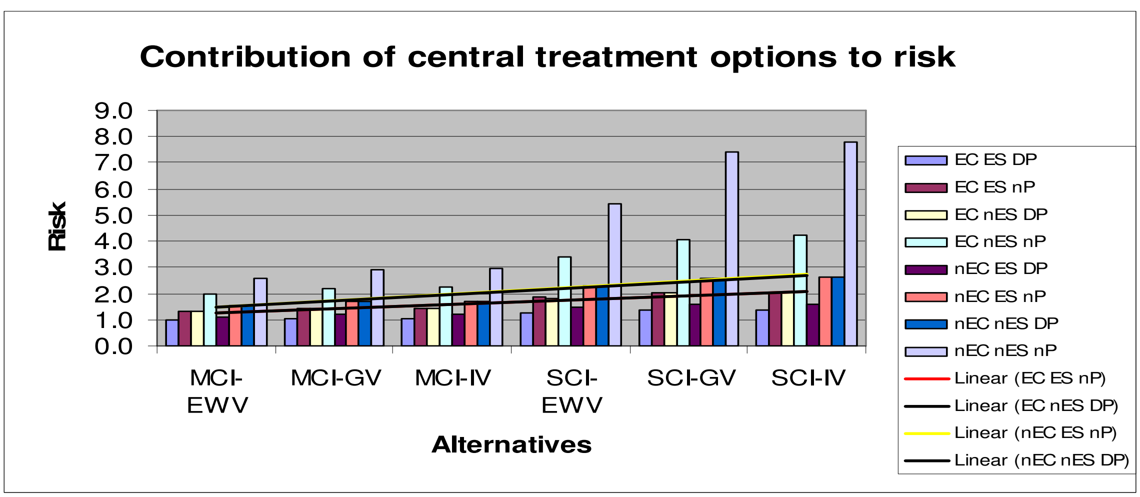


Figure 5.8(a): The contribution of central treatment options to risk

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The general trend seen is the increase of risk from the use of the **single chamber incinerator** (SCI) while the **multi-chamber incinerator** (MCI) decreases risk. The change of transport options from **engineered wheeled vehicle** (EWV) to **inappropriate vehicle** (IV) also results in an increase in the risk. The **non-engineered container** (nEC), **non-engineered storage** (nES) and **no procedures** (nP) combination of options contributes the most to risk, regardless of the transport and technology option chosen. EC, ES, DP is the combination that contributes the least to risk.

The gradient for the lines representing EC, ES, nP and EC, nES, DP is 0.166, implying that they reduce or increase risk to the same value. This means that a choice of **ES** reduces risk even if there are **no procedures,** or that **nES** can be used safely as long as **detailed procedures** are present. This is further confirmed by the gradients of the lines representing nEC, ES, nP (0.2516) and nEC, nES, DP (0.2505) which differ by a fraction of 1/1000. They can both be rounded off to 0.025. Figure 5.8(b) illustrates further the contribution of options from a second perspective.

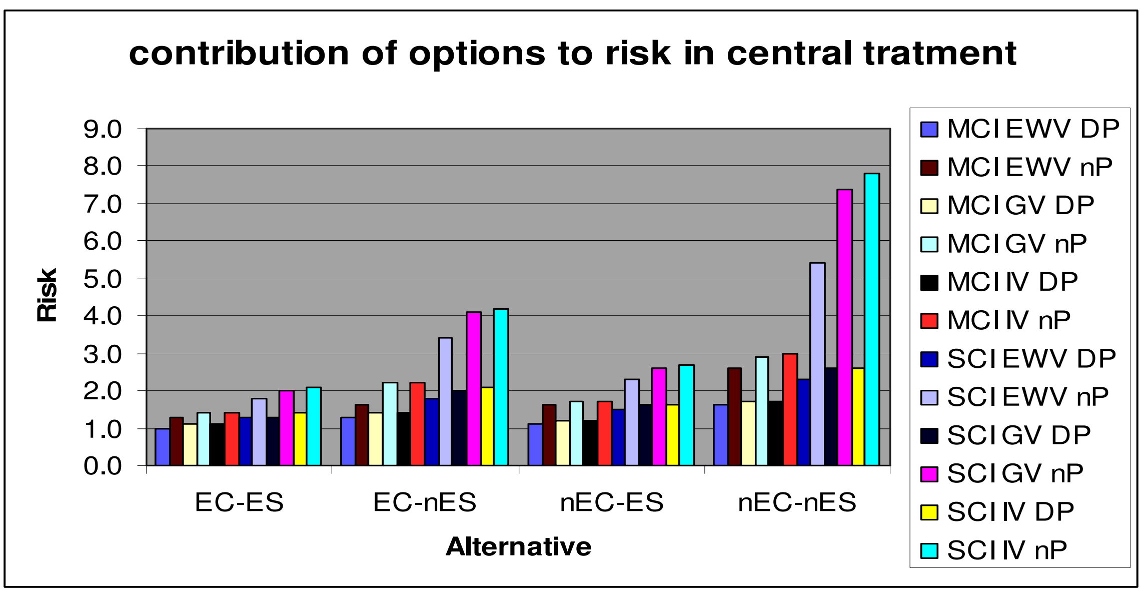
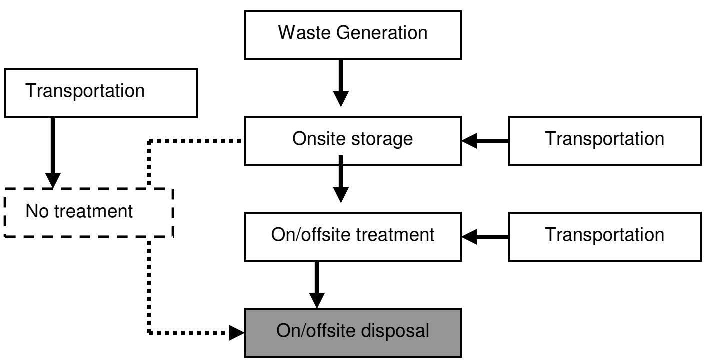


Figure 5.8(b): The contribution of central treatment options to risk

With the risk factors of **MCI, ES** and **SCI, ES** the lowest, it is proof that the element causing the reduction is **ES. EC, ES** reduces risk more than **nEC, ES** while **nEC, ES** reduces it more than **EC, nES**. The deduction is that **ES** is more important in reducing risk than **EC. GV, DP** and **IV, DP** are almost equal and thus **GV** and **IV** seem to have a similar contribution to the risk. The absence of **detailed procedures** is the largest contributor to risk.

In summary, for this life cycle phase the most significant option in reducing risk is **detailed procedures**, followed by **engineered storage**. The choice of transport, technology and containers are secondary to the first two.

5.3.6 Off-Site (Central) Disposal



Disposal technology/procedure options were plotted to result in Figure 5.9 below.

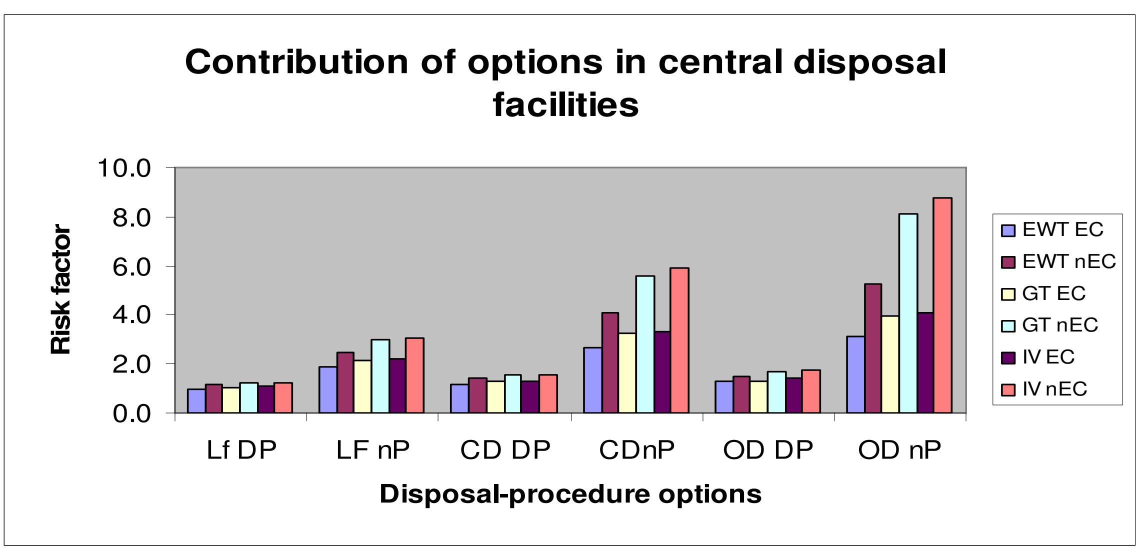


Figure 5.9: Contribution of off-site disposal options to risk

The general pattern seen is the increase of risk from **landfill** to **open dumping**, although the presence of **detailed procedures** would minimise the increase in risk. The largest contribution to risk is observed to be the use **of inappropriate vehicle (IV)** and **non-engineered container (nEC**). The second biggest contributor to risk is **general transport (GT)** and **non-engineered containers (nEC)**. It can be deduced that the transport mode is more important in this phase than the containers used. In agreement is the difference between **IV, EC and GT, EC**, which ranges from 3.1 % to 5.0 %. This small difference implies that the most important factor is the transport.

Transition from **LF** to **OD** increases the difference between **GT, nEC** and **IV, nEC**. Another important observation is that the presence of **detailed procedures** reduce risk to less than 2.0. **Open dumping** with **detailed procedures** is more important in reducing risk than a landfill run without procedures. Where **detailed procedures** are present the difference between **IV, nEC** and **GT, nEC** is negligible for all the disposal options. Low availability of equipment needs to be complemented with training.

The life cycle phase whose alternatives give the maximum risk is **central disposal** at 8.8, while the most risky alternative results from **onsite disposal** at 6.7. Correlating with Table 5.2 where the largest risk (12.0) is **inappropriate vehicle (IV)** in central treatment, none of the alternatives within central treatment poses the maximum risk for the phase. It is evident that options that pose more risk can be made less risky by combining with other less risky options.

In summary, for this life-cycle phase the choice of **detailed procedures** is the most important factor to minimise overall risks, followed by the choice of a formal disposal facility, an **engineered container** and then the mode of waste transportation.

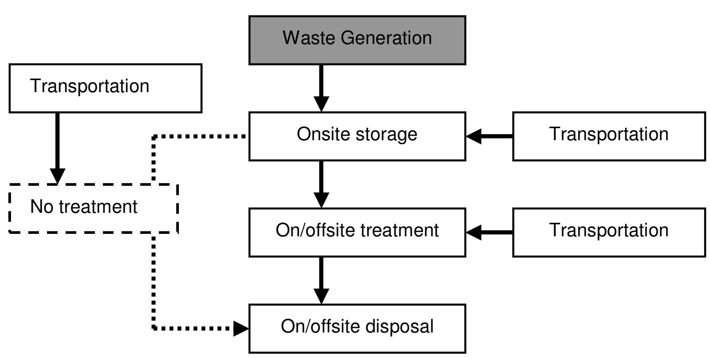
Table 5.3 below summarises the most important options that a decision-maker needs to consider per life cycle phase.

Table 5.3: Decision-making guide for the most important considerations

	First	Second	Third
Generation	Engineered container	Detailed procedures	Engineered location
Collection and Storage	Detailed procedures	Engineered transport	Engineered containers
Onsite treatment	Detailed procedures	Incineration technology	Engineered storage
Onsite disposal	Detailed procedures	Engineered pit technology	Engineered container
Offsite treatment	Detailed procedures	Engineered storage	Engineered transport
Offsite disposal	Detailed procedures	Landfill/Controlled dump	Engineered transport

5.4 CASE STUDIES

5.4.1 Waste Generation



(a) Waste generation

The most common types of health care waste generated were infectious waste and sharps. This is shown in Figure 5.10 below.

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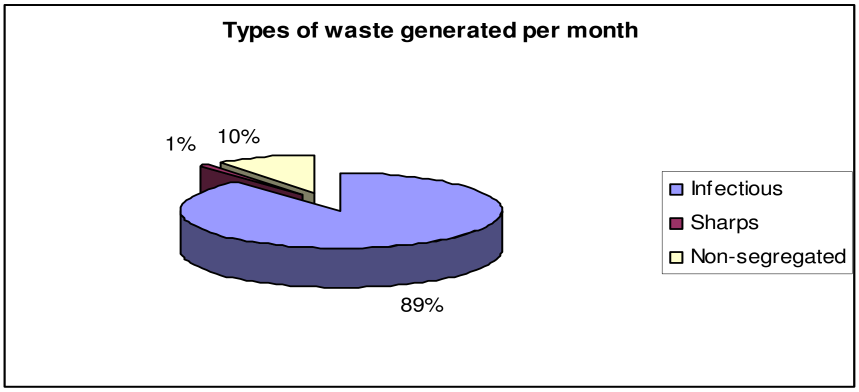


Figure 5.10: Waste generation rates

Non-segregated waste contains both sharps and infectious waste. Sharps generation is low due to a low prescription of injections to patients. Pharmaceutical waste is not depicted since only one clinic had generated this waste in a year and it is displayed as zero percent of the pie chart. Anatomical waste is generated only by three clinics. At St Leonard clinic an average of 20 deliveries of babies are done monthly due to the absence of a hospital in the area. The other two clinics perform deliveries on an emergency basis and thus the generation of anatomical waste is an average of two placentas per month.

The generation of sharps is shown in the following chart.

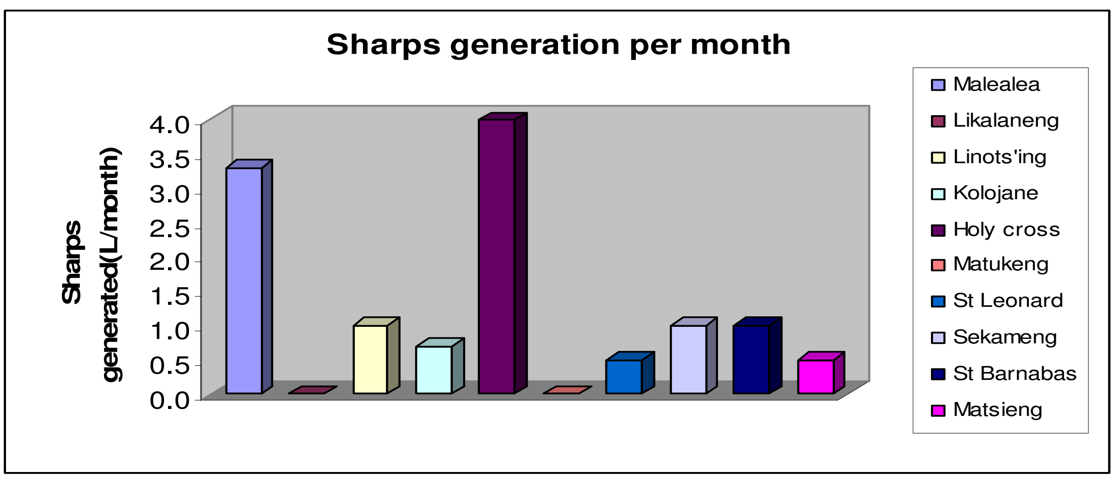


Figure 5.11: Generation of sharps per month (outpatients)

The centre that generates the most sharps is Holy Cross at 4.0 l/month. This is attributed to the size of the population in the clinic's service area (34644) compared to 2753 people in the area of Linots'ing health centre. Malealea is the second largest, generating 3.5 l/month despite the population of 5537. This implies that more prescriptions of injections are given here than in the other clinics. The clinics with zero generation are those whose sharps are not segregated.

(b) Waste segregation

Of the ten clinics, two (2) did not practice segregation of sharps and infectious waste at generation. Eight of the ten clinics did segregate sharps and infectious waste. Three of the ten clinics do deliveries and the anatomical waste generated is segregated. One clinic segregated pharmaceutical waste (which was collected during one year). Table 5.3 summarises the segregation findings.

Table 5.3: Waste segregation percentages by category

Waste Category	Number of Clinics	Percentage
Infectious	8	80 %
Sharps	8	80 %
Anatomical	3	30 %
Pharmaceutical	1	10 %
General	4	40 %
No segregation of HCW	2	20 %

(c) Container options

The major trend in these case studies was the use of non-engineered containers for infectious waste. The choice of the container-material depended on the preferences of the individual clinic. The container-material ranged from metal (stainless steel and enamel-coated steel/iron), cardboard and plastics. Some of the containers are shown in Figure 5.12. The use of engineered containers was observed for sharps. One clinic had sharps containers but did not segregate sharps from infectious waste. The most common engineered sharps container was the safety box (cardboard).

None of the clinics lined the containers. There is no individual or national colour-coding standard used in all the clinics.

Figure 5.12 (a-b): Containers at generation phase in two clinics

Table 5.4: The types of containers used in the clinics

Clinic	Infectious	Sharps	Anatomical	Pharmaceutical	Non-Segregate
Malealaea	Metal, covered	Engineered plastic	Metal	-	
Likalaneng				Box	Box, uncovered
Linots'ing	Plastic and box, uncovered	Non- engineered plastic		-	
Kolojane	Plastic, covered	Engineered box		-	
Holy Cross	Metal, covered box	Engineered box		-	
Matukeng	-	-	-	-	Metal, covered
St Leonard	Plastic, covered and uncovered	Engineered box	Metal, covered	-	
Sekameng	Box	Engineered box		-	
St Barnabas	Plastic and metal, covered	Engineered box	Metal	-	
Matsieng	Plastic, uncovered	Engineered box		-	

Seventy per cent (70 %) of the clinics use engineered containers for sharps, but in none of the other clinics do they have containers engineered to hold health care waste.

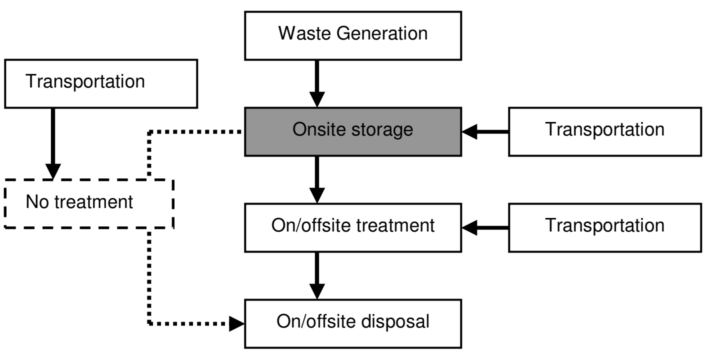
(d) Infrastructure

All the clinics visited did not have an engineered location for the primary storage of waste. Waste containers were placed either on the floor or on a table.

(e) Procedures

There are no national procedures or standards for the handling of waste during generation. No clinic has its own regulations for waste management during generation.

5.4.2 Collection and Storage



(a) Collection

In all the clinics cleaners do the collection. In 100 % of the cases infectious waste is collected at the end of the day (during cleaning). Anatomical waste is disposed off immediately after a delivery. In the case of sharps, collection occurs once the container is full. In all these clinics waste is carried by hand from the clinic to either disposal or treatment.

In two clinics (Holy Cross and Kolojane) aggregation of waste is practiced, from non-engineered containers to larger (80 *l*-100 *l*) non-engineered containers. The bigger container is emptied when full. At Kolojane aggregation takes place at the treatment site

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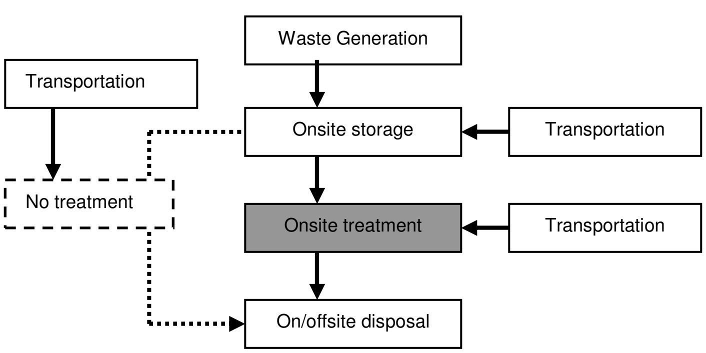
(b) Storage

Only one (Holy Cross) of the ten clinics has a specific area for storage. This is a non-engineered, non-refrigerated area. Unauthorized access to the area is easy. The area is also used as storage for cleaning materials. This area is shown in Figure 5.13 below.

Figure 5.13: Demarcated storage and aggregation area

There are no regulations, procedures or standards for the collection and secondary storage of health care waste. In one clinic a wheelbarrow (a non-engineered, wheeled) device is used for transporting waste.

5.4.3 On-Site Treatment



On-site treatment is the most common type of treatment in the rural clinics of Lesotho (Nine out of ten treat all their waste onsite). Half of the clinics (50 %) have an incinerator on site for waste treatment. One clinic treats its waste outside the boundaries of the clinic (about 20 meters away). The rest of the clinics treat infectious waste on-site. Sharps are transported to a central hospital by only one clinic. For nine (9) of the clinics waste is not stored at the treatment facility, therefore the container used to collect from the clinic is emptied and the waste treated. At one clinic (Malealea) waste is emptied into an on-site incinerator and stored for two to three days before treatment.

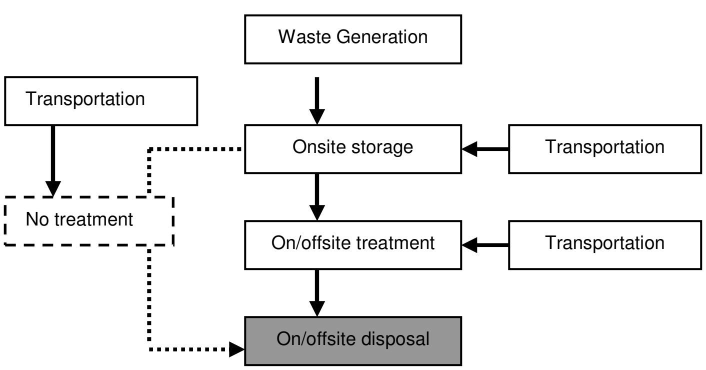
Due to the absence of a standard design and the absence of minimum requirements for incinerators, a variety of slightly different designs are used. The choice of the incinerator and its capacity depend on the funds available and on the design that contractors are able to propose to the clinic. The state of some incinerators suggests clearly their compromised performance in waste treatment. None of the incinerators has ideal controlled airflow and a measure of attainable temperatures. The residence time of waste in the incinerators vary. It is measured by looking at the reduction of the waste by fire. Turbulence is manual in all the incinerators and is provided by occasionally stirring the waste as it burns. Some of the incinerators and their state of performance is reflected in Figure 5.14 and figure 5.15.

Figure 5.14: Incinerator at Linots'ing Health centre

Figure 5.15: Incinerator used to store and treat waste at Malealea Health centre

In fifty percent of the clinics waste is treated by open air burning (although one clinic burns waste outside its boundaries). At Likalaneng health centre some HCW is burned openly and some is incinerated. Two clinics with incinerators reported that the incinerators give problems due to a lack of maintenance. At the other three there has not been a report of failure of their technologies. This is attributed to the fact that even if the door or a grate is missing, burning in the facility still continues.. Of the clinics with incinerators, none had detailed procedures for operating the incinerators. Procedures and regulations are absent for the whole treatment phase.

5.4.4 On-Site Disposal



In the five clinics where open air burning is practiced, the burning pit or ground is the final destination for the waste residue (it is left *in situ*). At St Leonard clinic an old pit latrine is used to dispose of the ash from incineration. The pit latrine (which is classified as a controlled dump in this research) is also used by three clinics for the disposal of placentas (anatomical waste). Table 5.5 gives a summary of the disposal methods.

Table 5.5: On-site waste disposal methods

Disposal Method	Engineered Pit	Controlled Dump (Pit Latrine)	Burning Pit
Number of clinics	0	3	7

Anatomical waste is disposed off untreated. It is transported for disposal in non-engineered containers. No clinic uses engineered containers for the transfer of ash to disposal sites. Only one clinic uses wheeled transport (wheelbarrow) to move ash. This is an inappropriate form of transport for waste residues. An observation made at the clinic is that the terrain is unsuitable for an open transport device, even if engineered.

No procedures are available regarding on-site disposal.

Off-site disposal as practiced currently is done by disposing of the waste on a small scale outside the premises of the clinic. It is not central disposal since the waste is not disposed at a facility like a village dump or a landfill. It is practiced by clinics to rid the clinic of filth, not because of lack of space within the clinic for on-site disposal. Current nurses do not know why it is done this way because they have taken over from others. The staff who practice this are aware that the waste residue is accessible to the public and know about the risks posed by potential contact with the residue. A typical off-site disposal area is shown below.

Figure 5.16: An off-site disposal area for waste at Kolojane clinic

5.4.5 Central Treatment and Disposal

This form of treatment is practiced on a very small scale in Lesotho. Central treatment facilities were subsequently outside the scope of the case studies.

5.4.6 Occupational Health and Safety

According to the WHO (World Health Organisation) Report (2002), infection control in health care waste management in some countries is achieved by post-exposure prophylaxis, hepatitis B virus immunisation, training of staff and improvement of waste management. The status of these points is discussed in the following sub- sections.

Vaccination

Despite the constant contact with patients at work, none of the clinical staff in all the clinics had been vaccinated against Hepatitis B. The risk of contracting the disease is high in case of transmission path availability. In all the clinics studied, there is no prophylactic treatment for suspected exposure to the AIDS virus (HIV).

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Needle stick injuries

Needle stick injuries are not reported formally in any of the clinics. There are no standards requiring the reporting of such and some injured personnel might be embarrassed to report. Clinical staff are injured mainly because of recapping needles after use on patients (nursing cadre). Waste-handling staff (cleaners and watchmen who normally burn waste or operate incinerators) are injured due to the inadequacy of protective clothing. Table 5.6 reflects the injuries incurred at the clinics.

Table 5.6: Overall needle stick injuries in ten clinics

	Nursing Cadre	Cleaners	Watchmen
Injuries in 0-12 months	4	1	0
Injuries in 13-60 months	1	0	1

The table shows that nursing staff is the most frequently injured. This is contrary to a study conducted in Jordan (McRae and Argawal, 1999) that reflected a 34.6 % injury to nurses and 60 % injury to technical staff. The main reasons for this discrepancy are likely to be the non-representative sample of these case studies. Lack of proper reporting of the injuries also implies that people rely entirely on memory, which may be vague.

Protective clothing

Protective clothing as prescribed by the WHO (Pruss *et al,* 1999) is not worn correctly by waste handlers. Different cadres of workers wear only parts of the set of apparel at different stages of the life cycle of waste handling. The main reason for the absence of the clothing is a shortage of funds. Some members of the staff are also ignorant about protective clothing. Negligence is also identified as a reason, because sometimes protective clothing is available but not used. During the generation of waste, the nursing staff members all wear examination gloves. The type of protective clothing worn by cleaners is reflected in Table 5.7.

Table 5.7: Protective clothing worn during waste handling

	None	Gloves Only	Gloves and Coverall
No. of clinics	1	7	2

Ninety percent of the clinics' staff wears gloves, either alone or combined with another piece of protective clothing. The gloves used are examination latex gloves, which are not recommended by the WHO. The WHO recommends heavy duty, long cuff plastic gloves (Pruss *et al,* 1999) for waste handling. In two of the clinics coveralls are also worn when handling waste.

Training of staff

Nursing/clinical staff

For the generators of waste there has been minimal formal training specifically for waste management. Knowledge of health care waste management is either attained through in-house knowledge transfer or as a topic in the major nursing training.

Cleaners and incinerator operators

In the five clinics that have incinerators, none of the operators had been trained in health care waste management or in operating the incinerator. Six clinic cleaners have acquired in-house knowledge, while four have had no training at all. Training packages have not been designed for cleaners, technicians and watchmen who handle waste in the country and there is no health care regulation requiring all waste handlers to undergo basic training.

Table 5.8: Training of waste handlers

	In-House Transfer Of Knowledge	Formal Course	Part of Major Training	No Training
Nurses	20 %	10 %	70 %	0
Cleaners	60 %	0	0	40 %
Watchmen	0	0	0	100 %

5.5 APPLICATION OF WASTEOPT TO CASE STUDY SCENARIOS

The risk of infection from waste at the clinics visited is shown below. This is achieved by adding up the alternative risk factors for the different life-cycle phases.

Table 5.9: Risk posed by waste HCWM at case study clinics

Clinic	Generation	WF	Collection/ Storage	WF	Treatment	WF	Disposal	WF	Risk
Malealea	nP+nEL+nEC	0.104	nEnW+nEC+nRnEF+nP	0.104	SASSI-M+IT+nEC+nES+nP	0.129	CD+nEC+nP	0.143	2.0×10^{-4}
Likalaneng	nP+nEL+nEC	0.104	nEnW+nEC+nRnEF+nP	0.104	SASSI-M+IT+nEC+nES+nP	0.129	OD+nEC+nP	0.111	1.5×10^{-4}
Linots'ing	nP+nEL+nEC	0.104	nEnW+nEC+nRnEF+nP	0.104	OAB+IT+nEC+nES+nP	0.092	OD+nEC+nP	0.111	1.5×10^{-4}
Kolojane	nP+nEL+nEC	0.104	nEC>nEC+nEnW+nEC+nRnEF+nP	0.073	SASSI-M+IT+nEC+nES+nP	0.129	OD+nEC+nP	0.111	1.1×10^{-4}
Holy Cross	nP+nEL+nEC	0.104	nEC>nEC+nEnW+nEC+nRnEF+nP	0.073	OAB+IT+nEC+nES+nP	0.092	OD+nEC+nP	0.111	7.8×10^{-5}
Matukeng	nP+nEL+nEC	0.104	nEnW+nEC+nRnEF+nP	0.104	OAB+IT+nEC+nES+nP	0.092	OD+nEC+nP	0.111	1.1×10^{-4}
St Leonard	nP+nEL+nEC	0.104	nEnW+nEC+nRnEF+nP	0.104	SASSI-M+IT+nEC+nES+nP	0.129	CD+nEC+nP	0.143	2.0×10^{-4}
Sekameng	nP+nEL+nEC	0.104	nEnW+nEC+nRnEF+nP	0.104	OAB+IT+nEC+nES+nP	0.092	OD+nEC+nP	0.111	1.1×10^{-4}
St Barnabas	nP+nEL+nEC	0.104	nEnW+nEC+nRnEF+nP	0.104	OAB+IT+nEC+nES+nP	0.092	OD+nEC+nP	0.111	1.1×10^{-4}
Matsieng	nP+nEL+nEC	0.104	nEnW+nEC+nRnEF+nP	0.104	OAB+IT+nEC+nES+nP	0.092	OD+nEC+nP	0.111	1.1×10^{-4}

- **WF = Weighting factor**
- **Values were obtained by multiplying weighting factors for alternatives**

A surprising observation is that the use of nEC with aggregation poses a lower risk than when nEC is used without aggregation. This is accounted for in the conclusion.

Incorporating EC in replacement of nEC in both aggregating and non-aggregating clinics reduces the risk by almost half.

5.6 FINANCING OF WASTE MANAGEMENT IN LESOTHO

The financial evaluation of the case studies was performed for certain topics and the findings thereof are shown below.

5.6.1 Funds Sustainability

The sustainability of funding for the overall running of the clinic was assessed on the source of the funds. All five public clinics source their funds from taxes (government). The CHAL-coordinated clinics have two sources of funding, user (service) fees and government grants. The private clinic sources funds from the Red Cross (grant).

Sustainability of funds is higher for public clinics since tax payers continually pay tax and government is commited to running these clinics. The grant to the private clinic is also sustainable and in case of it not meeting the budget, user fees may be spent. The user fees are spent as petty cash for daily operation of the clinic.

CHAL-clinics are subsidised by government for emoluments of clinical staff. There is currently a supplementary emergency financing facility (SEFF) from government that is given to selected clinics to upgrade their performance in relation to certain goals. The SEFF funding may not cover what the clinics deem the most important of their goals, e.g. purchase of drugs. SEFF is withdrawn once the clinic performs as required, even if the clinic still needs the fund. User fees are not a sustainable source of funds. As Garbutt (1992) explains, fees are normally fixed for a whole year, but significant unbudgeted costs may be incurred. Financial resources become inefficient. Government funding to public clinics is the most sustainable source.

5.6.2 Budgeting

All the clinics owned by government do not budget for themselves. Budgeting is done at district hospital level. Three of the four CHAL-clinics practice zero-base budgeting. This enables them to re-evaluate their objectives and goals while also motivating all entries of the budget. One of the four uses variable (incremental) budgeting. This allows for provision of funds for unforeseen events.

Waste management is not included in budgeting. Only one CHAL-clinic allocated 2 % of the budget for waste management, which is normally exceeded. None of the other clinics budgeted for waste management.

5.6.3 Accessibility of Funds

Public clinics do not handle cash to supply commodities. Their goals are achieved by ordering items and services (order system) from the district hospital. Four fifths of the public clinics reported that it is difficult to access commodities and services through the order system, while one finds it easy as long as the item is on the budget. The authorisation powers for transactions lie with the accounts section of the hospital.

CHAL-clinics manage their cash flow and the authorisation powers through the head nurse. All the CHAL-clinics find it easy to access funds if the item is budgeted for. The private clinic reports that it is conditionally easy (depends on availability of funds and prioritisation). Authorisation for spending lies with the organisation head office.

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Table 5.10: Methods engaged to control over and under spending

	CHAL	Public	Private
Ordering system (prior approval)	-	5	1
Adherence to budget	4	-	-
Diversion of funds	3	-	-
Comparing demand and consumption	2	-	-

5.6.4 Funds Utilization Control

All the public clinics and the private clinic only use the order system. CHAL-clinics have the biggest range of control of over and under spending. Adherence to the budget is the most frequently used while comparing demand and consumption is used by only two clinics. This expenditure-volume variance (Maitland, 1996) helps in forecasting and leads to purchase of only required commodities and avoids overspending.

5.6.5 Accountability Measures

Accounting for expenditure and revenue was assessed and the findings are shown in Table 5.11.

Table 5.11: Accountability for revenue and expenditure

	CHAL	Public	Private
Internal auditing	4	-	1
Periodic reporting	4	-	-
Receipts	4	5	1

Receipts accounting is standard to all clinics for revenue collected (user-fees) and petty cash used (private and CHAL-clinics). Public clinics account only for revenue collected and have the least issues to account for (less responsibility).

Table 5.12: Practices that promote waste management while adding revenue

	CHAL	Public	Private
Sale of waste plastic bottles	-	1	1
Re-use of re-usable commodities	-	2	-
None	2	4	

5.6.6 Cost Saving Practices

Sixty per cent of the clinics do not have cost-saving practices. Four of these clinics are public and do not have a specific section in the accounts for sales. The one clinic that sells drug bottles does this on a personal basis. There is no motivation from central administration to encourage such practices.

5.6.7 Targets for Savings

None of the clinics set targets to save money with regard to waste management.

5.6.8 Health Care Waste Management Costing

The current cost for waste management in the clinics could not be determined due to the reasons below.

Capital cost: The clinics with incinerators have no record of the capital cost of the incinerators.

Running costs: Clinics that use the open air burning method incur no cost for managing waste. Clinics that use incinerators incur no cost since fuel is not used.

5.7: THE COSTS OF TECHNOLOGIES

Table 5.13: Approximate costs of technologies

Component	Specifications	Option	Purchase price (Rand)	Replacement period	Running Cost/Month (Rand)	Cost/ L Waste/Month
Containers	*Choices for sharps*	Needle box (SA) 5 L	30.00	Single use	-	6.00
		Plastic sharps bucket 3 L	20.00	Single use	-	6.60
	Choices for infectious waste	Plastic waste baskets 12-15 L	70.00	5 years	0.28	0.75
		Stainless steel racks for plastic bags	300.00	5 Years	0	0
	For general waste	Plastic bags black 40 L	0.80	Single use	0	0.02
	For HCW	Plastic bags red 40 L	1.10	Single use	0	0.28
Engineered location	*Choices for engineered location*	Wall brackets	180.00	5 years	0	0
		Stainless steel waste trolley	1 700.00	5 years	1.12	0.75
Transportation	*Choices for on-site transport*	Wheelie bin 800 L	3 200.00	5 years	3.73	0.01
		Stainless steel bar fence trolley	1 500.00	5 years	3.73	0.75
		Wheelbarrow	300.00	5 Years	3.73	0.05
	Choices for off-site transport	Engineered vehicle	700,000.00	10 Years	3 340.00	0.30
		General vehicle	200,000.00	10 Years	4 380.00	0.70
		Inappropriate vehicle	1 000.00	10 Years	0	0

Storage	*Choices for on-site storage*	Engineered refrigerated facility	18 500.00	15 years	107.00	0.01
		Non-refrigerated engineered facility	12 000.00	20 years	28.00?	0
		Non-engineered non-refrigerated facility	7 000.00	20 Years	28.00?	0
Treatment	*Choices for on-site treatment*	SASSI-E	28 000.00	20 Years	8.00	0.64
		SASSI-M	17 000.00	20 Years	83.20	0.67
	Choices for off-site treatment	MCI	148 000.00	20 Years	33344.00	0.02
		SCI	60 000.00	20 Years	32.00	0.13
Disposal	*Choices for on-site disposal*	Engineered pit	10 000.00	10 Years	0	0
		Controlled dump (on-site)	2 500.00	20 Years	0	0
		Controlled dump (central)	250 000.00	20 Years	60.00	0.48
		Landfill	20 000 000.00	20 Years	1.05	1.05
		Open dump	0	-	0	0
Procedures		Detailed procedures	70.000.00	-	0	0

Table 5.14: Approximate costs for protective clothing

Option	Total Cost Per Unit (Rands)
Nose mask	30.00
Overalls	250.00
Aprons	120.00
Long cuff tough plastic gloves	100.00
Heavy duty boots	350.00
Safety goggles (for exploding vaccine bottles)	120.00

CHAPTER 6

Conclusions and recommendations

The contradictory and surprising findings of the study are presented in this chapter together with possible reasons for their existence. The research questions of this study are also revisited. The key findings are further linked with the literature. Finally recommendations are made that may enhance the health care waste management system of Lesotho.

6.1 RESEARCH RESULTS

6.1.1 The AHP

The analytical hierarchy process (AHP) has not been applied before in healthcare waste management (HCWM) in rural areas. In this research, WasteOpt, a tool that combines the AHP and life cycle approaches was developed and applied successfully to the management of health care waste. The findings reveal that the risk of infection by HCW increases with the absence of environmentally sound technologies, i.e., engineered technologies, procedures and infrastructure. From these findings, options and alternatives can be selected which minimise this risk. This leads to informed decision-making and thus the construction of a working HCWM system. The information on risk also is a step towards bridging the gap between developed and developing countries. It is evidently important to select and combine first world tools objectively for their successful application. WasteOpt has proved to be an ideal tool for health care waste management in a developing country.

The calculated risk factors, however, remain as comparative and not purely quantitative risk because the life cycle impact assessment stage (as stipulated in ISO 14042) has been partially bypassed. The risk factors are also based on judgements made by HCWM experts.

The finding that some non-Environmentally Sound Technologies (EST), e.g. open air burning (OAB), can be combined with detailed procedures in the alternative, i.e. Open air burning+ Engineered wheeled transport+ Engineered containers +Engineered storage +Detailed procedures (OAB+EWT+EC+ES+DP) to minimise risk (risk = 1.2), also affirm the fact that the cost of prevention of infection is lower than waiting to treat the infections (some of which are incurable).

The choice of the low-risk alternatives to implement requires adherence to standards, but due to the absence of such in Lesotho the cost of implementing and maintaining these alternatives still plays the determining role.

Although some clinics continue to construct non-engineered technologies uncontrolled by any agency, these are viewed as interim strategies that might need upgrading when standards come into action. This contradicts statements made by health care waste strategic planners.

- "Quality of technologies and procedures should not be compromised due to lack of funds. Planning should be focused on systems that work and are sustainable, rather that on interim strategies" (Siimane *et al*, 2005), appendix 2.
- "It is advisable to always have a backup alternative at health facilities in case technologies fail" (Siimane *et al*, 2005), appendix 2.

The backup alternatives mentioned above were not specified or included as options in the weighting done in the workshop. A gap is thus identified that if all these available options were included, the outcome could have remarkably differed from the current findings.

Environmentally sound technologies were assessed in terms of cost effectiveness and risk reduction efficiency. Individual options that have lowest risk factor (Risk = 1.0) are presented below (classified as on-site and off-site technologies):

Onsite technologies	**Offsite technologies**
Engineered containers	Engineered wheeled transport
Engineered location/storage	Refrigerated engineered facility
Detailed procedures	Multi-chamber incinerator
Engineered pit	Landfill

Engineered containers, detailed procedures and engineered wheeled transport are crosscutting for onsite and offsite applications.

These alternatives that minimise risk were selected by low risk and lowest cost per litre of waste.

[The key to these abbreviations can be found the list of technical terms on page v]

Alternatives that contain EC are not included as low risk, low cost alternatives since the cost of containers is high. Containers have, however, been identified as very important in reducing risk. The decision-maker may opt for such alternatives because containers are cross-cutting in all phases. Investing in containers at an early phase like generation may mean the cost of containers need not be added to costing at later phases.

Generation (Option costs from table 5.13 added per alternative)

DP+EL+nEC	1.5
DP+nEL+nEC	1.2

Collection and storage

nEC>nEC+EW+nEC+nREF+DP	1.4
nEC>nEC+EW+nEC+nRnEF+DP	1.6
nEC>nEC+nEnW+nEC+nREF+DP	1.5
nEC>nEC+nEnW+nEC+nRnEF+DP	1.6

Refrigerated engineered facilities are expensive to implement and maintain. Alternatives with REF are sustainable in urban central locations due to lack of electricity in rural areas. Engineered wheeled transport is also usable in such areas. Therefore alternatives with nREF and nRnEF are cost effective for rural clinics. All alternatives with EC are excluded due to the cost: including those with nEC>nEC + EC… since one can not aggregate this way with engineered containers involved.

Onsite treatment

OAB+ EWT+nEC+ES+DP	1.3
OAB +GT +nEC+ES+DP	1.5
OAB+IT+nEC+ES+DP	1.5
SASSI-M+EWT+nEC+ES+DP	1.4
SASSI-E+IT+nEC+ES+DP	1.2
SASSI-M+GT+NEC+ES+DP	1.4

SASSI-M+IT+NEC+ES+DP	1.4
Onsite disposal	
OD+nEC+DP	1.7
EP+nEC+DP	1.2
CD+nEC+DP	1.6
Offsite treatment	
MCI+EWV+nEC+ES+DP	1.1
MCI+EWV+nEC+nES+DP	1.6
MCI+GV+nEC+nES+DP	1.7
MCI+GV+nEC+ES+DP	1.2
MCI+IV+nEC+ES+DP	1.2
MCI+IV+nEC+nES+DP	1.7
SCI+EWV+nEC+ES+DP	1.5
SCI+GV+nEC+ES+DP	1.6
SCI+IV+nEC+ES+DP	1.6
Offsite disposal	
LF+IV+nEC+DP	1.3
OD+EWV+nEC+DP	1.5
OD+GV+nEC+DP	1.7
OD+IV+nEC+DP	1.7
CD+EWV+nEC+DP	1.4
CD+GV+nEC+DP	1.3
CD+IV+nEC+DP	1.6

6.1.2 Workshop

Participants were knowledgeable about the technologies discussed. The reason for the current waste management situation is due to indecisiveness on what the best combination of options is. This is further complicated by the lack of financial resources to assemble the technologies deemed to be safe. Health care waste management has also not been based on procedures, which were found to reduce the risk of infection considerably.

Participants operating at policy level were more informed than implementers in terms of current interventions, policies, programmes and plans at both national and international levels. This could imply an information transfer block between the levels and also a low level of involvement of the lower levels in decision-making.

A contradiction was seen in the approach to options to be compared. Among the treatment technologies, incineration methods only were retained as applicable. This was because all the other methods, e.g. microwave radiation, dry sterilisation etc. have not been used or considered for use in Lesotho. On the contrary, for offsite disposal landfilling and controlled dumping were accepted as options, although they have not been used in the country. This is attributed to the fact that these technologies are being considered for implementation.

6.1.3 Modification of the Rapid Assessment Tool

The application of the modified RAT (rapid assessment tool) showed that in terms of priority setting and financial allocation, health care waste management has been compromised. Health care facilities do not budget for health care waste management and are unable therefore to raise capital for relevant investments.

RAT has a question on budgeting but including more finance-related questions will help health facilities to consider waste management seriously as part of the health provision package. Poor funding which is prevalent in developing countries can also be controlled, because cost-effective options and alternatives can be selected.

6.1.4 Case studies

The status quo of health care waste management in the clinics is highly risky (risk ranges from 2.0×10^{-4} to 7.8×10^{-5}).

In terms of financial management, Christian Health Association of Lesotho (CHAL) coordinated clinics are the most independent. They manage their budgeting, fundraising and expenditure. The managers operate in transparency. The advantage of carrying funds over to a new financial period enables them to save for capital investment.

Public clinics however, operate with little information on their finances. The use of the order system which is controlled from the district hospital encourages low control and accountability for funds. The private clinic also has no autonomy in the use of funds, but operate in transparency compared to public clinics.

CHAL clinics have the highest potential for implementing environmentally sound technologies than public clinics.

In conclusion, the application of the technologies and options mentioned above is a step towards the safety of public health and the environment. The following objectives have been realised:

- Quantitative: impacts that are directly measurable and an estimate of its uncertainty can be made, e.g. the cost associated with a certain unit process in the life cycle.
- Qualitative: non-quantitative impacts that can be assigned a risk based on expert assessment.

6.1.5 WasteOpt as a model to identify EST's for Lesotho

The choice of WasteOpt as a decision-making tool to identify EST's for a developing country is based on its appropriateness to HCWM at all levels of administration and implementation in health care. This section will identify and discuss the advantages and benefits of WasteOpt in relation to decision-making tools available for EST identification in Lesotho. The use of the hierarchy of waste management alone will not necessarily lead to economically and otherwise sustainable systems, because it does not attempt to measure the impacts of the individual options available (White *et al.*, 1995). The WasteOpt model has the following benefits:

- It provides rapid information on ranking of options because it is tailored for the level of information available (Rogers *et al.*, 2002). Unlike in the developed world where there is enough information for decision-making, the developing world has limited information. WasteOpt encourages the use of available data. It is thus simple to apply and can encourage the acquisition of more specific data.

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- It can be used in strategic planning, enabling the comparison between actual and acceptable practice. Analysis of current policy and legal framework resulting from this strategic planning could lead to positive action in terms of enforcement of laws and compliance thereto.
- It presents the costs of implementing and operating a working waste management system. Since the tool attempts to strike a balance between risk and cost, then budgets will be made for systems that are appropriate for the specific region, the available human resource base and available funding.
- The tool presents the overall risk of direct and indirect exposure of health care workers and the public at large. Such information could empower the public in terms of environmental and health awareness and thus lead to them being more participative in HCWM. With an empowered and enlightened public work force, governments and the public could promote public-private partnerships in waste management.

WasteOpt helps overcome some of the characteristic handicaps of developing countries as shown in table 6.1 below:

Table 6.1: WasteOpt's solution to Lesotho's HCWM handicaps

Current Handicaps in Lesotho's HCWM programmes	**WasteOpt's Strengths/Responses**
Lack of policies and guidelines for responsible HCWM	Procedures, Infrastructure and technology components are a good common base for policy and guideline formulation
Inadequacy of current legislation to address HCW	Laws will be promulgated based on choices that are easy to implement for Lesotho
Inadequate financial and human resources	Low cost, low risk options and alternatives are identified
Slow decision-making process	HCWM stakeholders decide together with limited human judgement biases
Lack of quantitative (actual or comparative) risk factors	Quantified comparative risk factors are calculated
Slow implementation of plans	Identified low-risk, low-cost alternatives require less finances (ease of funds allocation) and have reduced risk to workers.
Inadequacy of data on the HCWM system	WasteOpt is tailor-made to deal with available data

The prerequisites for the application of WasteOpt as it was applied in the study are:

- Involvement of all stakeholders
- Definition of the current HCWM system
- Compilation of a database of all available HCW technologies that are specific for the area
- Pairwise comparison of options and risk factor calculations
- Identification of ESTs based on risk
- Compilation of costs for technologies
- Calculation of the cost for each EST alternative
- Selection of lo-risk, low-cost ESTs

Finally, WasteOpt was proved to be viable decision-making tool. As it has been proven to be applicable in Lesotho and its applicability to other developing countries e.g. in Asia can be tested. A nation protected from infectious diseases through environmentally sound HCWM can overcome other barriers that hamper sustainable development.

6.2 RECOMMENDATIONS

6.2.1 Further research

Several improvements could be made to this research. First, it would be desirable to include more health care waste management technologies, especially non-incineration treatment options. From literature consulted, it is evident that incineration as practiced in developed countries is an addition to environmental risk which secondary affects human health. Many options have been left out due to the inadequacy of time and scarcity of information on these technologies.

In addition, the cost data used in this research needs to be updated to encompass taxes for imported technologies as well as transportation costs for remote and difficult-to-access health care facilities.

Thirdly, the methodology used for risk measurement could be enhanced to include environmental risks, not just risk to human health. A fourth improvement could be the application of this research's methodology to hospitals in both urban and rural settings, to assess the difference in risk between the two settings. It can also be applied to district or health service areas to standardise regional health care waste management. The methodology is perceived to have the capability of defining the tradeoffs of introducing local recycling facilities.

A fifth improvement could be the application of the AHP in different sectors of waste management, e.g. industrial solid and liquid, waste as well as municipal solid waste.

6.2.2 Financing

- In Lesotho it is vital that public clinics be allocated funds in the style of a cost centre such that they are able to manage their funding, budgeting and investment requirements like the CHAL clinics.
- Health care waste management should be regarded as a priority when budgeting and implementing health care objectives.

6.2.3 National administration

- At national and, if need be, at district level, standards should be formulated or adopted to establish the minimum requirements for handling health care waste from ''cradle to grave''.
- Small-scale incinerators are to be designed according to given national standard and tested for use.
- Relevant ministries should encourage health care workers and policy-makers to view HCWM as part of the health care system and not just an individual step. This can be achieved by training. It is also important that health care workers are motivated to take HCWM seriously and implement tactics to improve it.
- Other relevant health policies should be made in order to support HCWM, e.g. a national safe injections policy may specify types of syringes and Environmentally Sound Technologies for treatment and disposal.

- Health care facilities should initiate and practice environmentally preferable purchasing as a control for the hazardousness of the waste generated.
- Reporting of occupational injuries and standardisation of the availability of prophylaxis for all health care workers should be adapted as a norm in all clinics and hospitals.
- Emergency preparedness and response programmes should be put in place for all potential hazards of health care waste.
- It is recommended that a database be established to store information and health care waste sources, collection, transportation, treatment and disposal. This requires proper recording. Components and composition of HCW to are to be established.
- Training packages need to be designed for the different cadres handling health care waste. This needs also to be included in curricula of relevant courses at academic institutions.

6.2.4 Public participation

- New alliances between public, private and civic sectors need to be established to help to tackle some of the entrenched obstacles and resistance to change.
- Government should put in place a framework of incentives and regulations to steer demand towards sustainable consumption for all types of organisations and business.
- Citizen organisations should take initiatives to mobilise public involvement, enthusiasm and action for changes in sustainable consumption and waste management. This may require the need to form environmental protection or activist organisations.

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APPENDICES

APPENDIX 1: AHP RESULTS

Table 1: AHP results obtained from the workshop participants for the **waste generation** life cycle phase.

Options	Participants											Average weight
	1	2	3	4	5	6	7	8	9	10	11	
Level 2												
Container	0.413	0.333	0.333	0.333	0.333	0.333	0.333	0.778	0.279	0.243	0.455	**0.375**
Infrastructure	0.260	0.333	0.333	0.333	0.333	0.333	0.333	0.111	0.072	0.056	0.091	**0.235**
Procedures	0.327	0.333	0.333	0.333	0.333	0.333	0.333	0.111	0.649	0.701	0.455	**0.386**
Consistency	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.056	0.093	0.000	
Level 3												
EC	0.833	0.875	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.833	0.857	**0.882**
nEC	0.167	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.167	0.143	**0.118**
Consistency												
EL	0.875	0.875	0.900	0.900	0.900	0.900	0.900	0.875	0.900	0.750	0.800	**0.870**
nEL	0.125	0.125	0.100	0.100	0.100	0.100	0.100	0.125	0.100	0.250	0.200	**0.130**
Consistency												
DP	0.875	0.875	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.889	0.857	**0.891**
nP	0.125	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.111	0.143	**0.109**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Table2: Weighting results obtained from the workshop participants for the **collection and storage** life cycle phase.

Options	Participants											Average weight
	1	2	3	4	5	6	7	8	9	10	11	
Level 2												
Tech/Agg.	0.069	0.067	0.063	0.818	0.333	0.104	0.333	0.333	0.471	0.200	0.678	**0.315**
Inrastructure	0.244	0.467	0.458	0.091	0.333	0.127	0.333	0.333	0.059	0.200	0.142	**0.253**
Procedures	0.687	0.467	0.478	0.091	0.333	0.769	0.333	0.333	0.471	0.600	0.179	**0.431**
Consistency	0.107	0.000	0.002	0.000	0.000	0.033	0.000	0.000	0.000	0.000	0.046	
Aggregation	0.059	0.067	0.818	0.818	0.250	0.095	0.634	0.481	0.471	0.149	0.129	**0.391**
Transport	0.240	0.467	0.091	0.091	0.250	0.250	0.174	0.056	0.059	0.66	0.085	**0.159**
Container	0.701	0.467	0.091	0.091	0.500	0.655	0.192	0.463	0.471	0.785	0.785	**0.450**
Consistency	0.254	0.000	0.000	0.000	0.000	0.063	0.008	0.001	0.000	0.069	0.066	
Level 3												
EC>EC	0.293	0.377	0.377	0.207	0.207	0.2550	0.653	0.750	0.692	0.568	0.501	**0.467**
EC>nEC	0.293	0.072	0.073	0.207	0.207	0.250	0.228	0.083	0.140	0.313	0.251	**0.192**
nEC>EC	0.207	0.496	0.496	0.293	0.293	0.250	0.060	0.083	0.070	0.069	0.251	**0.223**
nEC>nEC	0.207	0.055	0.055	0.293	0.293	0.250	0.060	0.083	0.098	0.042	0.037	**0.118**
Consistency	0.045	0.045	0.057	0.091	0.091	0.155	0.091	0.000	0.091	0.063	0.068	
EW	0.731	0.735	0.743	0.582	0.751	0.743	0.796	0.102	0.205	0.731	0.798	**0.671**
EnW	0.188	0.207	0.194	0.367	0.178	0.194	0.125	0.726	0.722	0.188	0.138	**0.251**
nEnW	0.081	0.058	0.063	0.051	0.070	0.063	0.079	0.172	0.073	0.081	0.064	**0.251**
Consistency	0.056	0.100	0.061	0.046	0.025	0.061	0.046	0.025	0.107	0.056	0.093	
EC	0.875	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.875	0.857	**0.892**
nEC	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.143	**0.108**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
REF	0.731	0.773	0.818	0.672	0.627	0.582	0.663	0.725	0.635	0.649	0.655	**0.685**
nREF	0.188	0.139	0.091	0.265	0.256	0.367	0.278	0.207	0.287	0.279	0.290	**0.241**
nRnEF	0.081	0.046	0.091	0.065	0.063	0.051	0.058	0.058	0.078	0.072	0.055	**0.069**
Consistency	0.056	0.046	0.000	0.025	0.025	0.046	0.046	0.101	0.081	0.056	0.069	
DP	0.889	0.889	0.900	0.900	0.900	0.900	0.875	0.875	0.900	0.833	0.857	**0.883**
nP	0.111	0.111	0.100	0.100	0.100	0.100	0.125	0.125	0.100	0.167	0.143	**0.117**
Consistency	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000	0.000	0.000	0.000	

Table 3: Weighting results obtained from the workshop participants for the **onsite waste treatment** life cycle phase.

Option	Participants											Average weight
	1	2	3	4	5	6	7	8	9	10	11	
Level 2												
Tech./Equip	0.416	0.413	0.413	0.333	0.333	0.413	0.333	0.413	0.444	0.462	0.773	**0.431**
Infrastructure	0.126	0.260	0.260	0.333	0.333	0.260	0.333	0.260	0.111	0.077	0.134	**0.226**
Procedures	0.458	0.327	0.327	0.333	0.333	0.327	0.333	0.327	0.444	0.462	0.093	**0.342**
Consistency	0.008	0.046	0.046	0.000	0.000	0.046	0.000	0.046	0.000	0.000	0.093	
Technology	0.687	0.659	0.550	0.250	0.250	0.515	0.429	0.785	0.333	0.714	0.482	**0.514**
Transport	0.069	0.185	0.210	0.250	0.250	0.097	0.143	0.149	0.333	0.143	0.091	**0.175**
Container	0.244	0.156	0.240	0.500	0.500	0.388	0.429	0.066	0.333	0.143	0.429	**0.311**
Consistency	0.107	0.025	0.016	0.000	0.000	0.069	0.000	0.046	0.000	0.000	0.013	
Level 3												
SASSI-E	0.641	0.655	0.655	0.717	0.735	0.606	0.735	0.763	0.733	0.644	0.648	**0.685**
SASSI-M	0.293	0.290	0.290	0.217	0.207	0.333	0.207	0.176	0.199	0.271	0.300	**0.253**
OAB	0.067	0.055	0.055	0.066	0.058	0.061	0.051	0.061	0.068	0.085	0.052	**0.062**
Consistency	0.086	0.069	0.069	0.032	0.101	0.008	0.101	0.093	0.081	0.046	0.093	
EWT	0.777	0.785	0.793	0.770	0.770	0.777	0.773	0.696	0.761	0.699	0.655	**0.751**
GT	0.153	0.149	0.131	0.162	0.162	0.153	0.139	0.229	0.166	0.237	0.290	**0.179**
IT	0.007	0.066	0.076	0.168	0.168	0.070	0.088	0.075	0.073	0.064	0.055	**0.088**
Consistency	0.090	0.069	0.019	0.046	0.046	0.090	0.046	0.066	0.063	0.081	0.069	
EC	0.889	0.875	0.900	0.900	0.900	0.900	0.875	0.889	0.900	0.833	0.875	**0.885**
nEC	0.111	0.125	0.100	0.100	0.100	0.100	0.125	0.111	0.100	0.167	0.125	**0.115**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
ES	0.857	0.875	0.875	0.900	0.900	0.900	0.875	0.889	0.900	0.750	0.889	**0.874**
nES	0.143	0.125	0.125	0.100	0.100	0.100	0.125	0.111	0.100	0.250	0.111	**0.126**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
DP	0.833	0.875	0.875	0.900	0.900	0.900	0.875	0.889	0.900	0.875	0.900	**0.884**
nP	0.167	0.125	0.125	0.100	0.100	0.100	0.125	0.111	0.100	0.125	0.100	**0.116**
Consistency												

Table 4: Weighting results obtained from the workshop participants for the **onsite waste disposal** life cycle phase.

Option	Participants											Average weight
	1	2	3	4	5	6	7	8	9	10	11	
Level 2												
Tech/Equip	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.883	0.800	**0.558**
Procedures	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.116	0.200	**0.442**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Technology	0.500	0.875	0.875	0.333	0.333	0.500	0.500	0.800	0.500	0.800	0.875	**0.626**
Container	0.500	0.125	0.125	0.667	0.667	0.500	0.500	0.200	0.500	0.200	0.128	**0.374**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Level 3												
EP	0.641	0.641	0.592	0.751	0.751	0.714	0.796	0.796	0.763	0.701	0.767	**0.719**
CD	0.293	0.297	0.333	0.178	0.178	0.143	0.079	0.079	0.176	0.243	0.176	**0.196**
OD	0.067	0.072	0.075	0.070	0.070	0.143	0.125	0.125	0.061	0.056	0.061	**0.084**
Consistency	0.086	0.086	0.012	0.025	0.025	0.000	0.046	0.046	0.093	0.093	0.093	
EC	0.889	0.875	0.875	0.0900	0.900	0.900	0.889	0.857	0.900	0.833	0.857	**0.880**
nEC	0.111	0.125	0.125	0.100	0.100	0.100	0.111	0.143	0.100	0.167	0.143	**0.120**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
DP	0.875	0.900	0.900	0.900	0.900	0.900	0.900	0.875	0.900	0.750	0.889	**0.881**
nP	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.100	0.250	0.111	**0.119**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Table 5: Weighting results obtained from the workshop participants for the offsite (**central) waste treatment** life cycle phase.

Option	Participants											Average weight
	1	2	3	4	5	6	7	8	9	10	11	
Level 2												
Tech/Equip	0.687	0.714	0.714	0.333	0.333	0.600	0.333	0.444	0.333	0.333	0.528	**0.487**
Infrastructure	0.186	0.143	0.143	0.333	0.333	0.200	0.333	0.084	0.333	0.333	0.091	**0.228**
Procedures	0.127	0.143	0.143	0.333	0.333	0.200	0.333	0.472	0.333	0.333	0.381	**0.285**
Consistency	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.093	
Technology	0.594	0.667	0.667	0.250	0.250	0.429	0.429	0.687	0.672	0.667	0.761	**0.552**
Transport	0.157	0.167	0.167	0.250	0.250	0.143	0.143	0.069	0.063	0.167	0.166	**0.158**
Container	0.249	0.167	0.167	0.500	0.500	0.429	0.429	0.244	0.265	0.167	0.073	**0.290**
Consistency	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.107	0.025	0.000	0.063	
Level 3												
MCI	0.833	0.833	0.833	0.875	0.875	0.857	0.857	0.889	0.875	0.857	0.833	**0.856**
SCI	0.167	0.167	0.167	0.125	0.125	0.143	0.143	0.111	0.125	0.143	0.167	**0.144**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
EWV	0.777	0.743	0.743	0.751	0.751	0.799	0.799	0.707	0.785	0.761	0.770	**0.762**
GV	0.153	0.194	0.194	0.178	0.178	0.105	0.105	0.223	0.149	0.166	0.162	**0.164**
IV	0.070	0.063	0.063	0.070	0.070	0.096	0.096	0.070	0.066	0.073	0.068	**0.164**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
EC	0.875	0.900	0.900	0.900	0.900	0.900	0.900	0.889	0.900	0.857	0.889	**0.892**
nEC	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.111	0.100	0.143	0.111	**0.118**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
ES	0.889	0.900	0.900	0.900	0.900	0.900	0.900	0.875	0..900	0.857	0.900	**0.893**
nES	0.111	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.100	0.143	0.100	**0.107**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
DP	0.875	0.900	0.900	0.900	0.900	0.900	0.900	0.889	0.900	0.889	0.889	**0.895**
nP	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.111	0.100	0.111	0.111	**0.105**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Table 6: Weighting results obtained from the workshop participants for offsite **central waste disposal.**

Option	Participants											Average weight
	1	2	3	4	5	6	7	8	9	10	11	
Level 2												
Tech/Equip	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.900	**0.890**
Procedures	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.100	**0.110**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Technology	0.761	0.800	0.509	0.250	0.250	0.458	0.429	0.333	0.333	0.714	0.766	**0.539**
Transport	0.073	0.100	0.097	0.250	0.250	0.063	0.143	0.333	0.333	0.143	0.125	**0.174**
Container	0.166	0.100	0.094	0.500	0.500	0.479	0.429	0.333	0.333	0.143	0.125	**0.287**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Level 3												
LF	0.467	0.750	0.750	0.735	0.735	0.804	0.592	0.722	0.722	0.763	0.481	**0.686**
CD	0.467	0.171	0.171	0.207	0.207	0.122	0.333	0.222	0.227	0.176	0.463	**0.248**
OD	0.067	0.078	0.078	0.058	0.058	0.074	0.075	0.051	0.051	0.061	0.056	**0.066**
Consistency												
EWV	0.777	0.798	0.798	0.761	0.761	0.818	0.777	0.798	0.663	0.763	0.751	**0.770**
GV	0.153	0.138	0.138	0.158	0.158	0.091	0.153	0.138	0.278	0.176	0.178	**0.160**
IV	0.070	0.064	0.064	0.082	0.082	0.091	0.070	0.064	0.058	0.061	0.070	**0.071**
Consistency	0.090	0.093	0.093	0.001	0.001	0.000	0.090	0.093	0.046	0.093	0.025	
EC	0.889	0.889	0.889	0.900	0.900	0.900	0.889	0.889	0.900	0.857	0.889	**0.890**
nEC	0.111	0.111	0.111	0.100	0.100	0.100	0.111	0.111	0.100	0.143	0.111	**0.110**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
DP	0.875	0.875	0.889	0.900	0.900	0.900	0.889	0.889	0.900	0.875	0.900	**0.890**
nP	0.125	0.125	0.111	0.100	0.100	0.100	0.111	0.111	0.100	0.125	0.100	**0.109**
Consistency	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

APPENDIX 2: THE WORKSHOP REPORT

Establishing weighting values for waste management options at primary health care facilities in under serviced areas of Lesotho

A Workshop Held at Bambatha Ts'ita Arena on the 6th-7th April 2005

Report Prepared by
Ts'aletseng Siimane
Dr Alan Brent
Dr David Roger

LIST OF TABLES

LIST OF ACRONYMS

CHAL:	Christian Health Association of Lesotho
EST:	Environmentally Sound Technology
HCW:	Health Care Waste
HCWM:	Health Care Waste Management
MoHSW:	Ministry of Health and Social welfare
MoTEC:	Ministry of Tourism, Environment and Culture
NES:	National Environment Secretariat
NHCWMP:	National Healthcare Waste Management Plans
PHC:	Primary Health Care

1. INTRODUCTION

The two-day workshop was sponsored by the Development Corporation of Ireland (DCI) under the Health Planning unit of the Ministry of Health and Social Welfare. It was held as an aid for a postgraduate data-gathering exercise from experts in the field of healthcare waste management in Lesotho. DCI has supported the overall MSc programme since July 2003.

The participants of the workshop came from both district and national levels. An average of 14, highly engaged participants was registered per day for the two days.

The facilitators of the workshop were Drs Alan Brent, David Rogers and Godfrey Mvuma who came from the University of Pretoria, Council for Scientific and Industrial Research (CSIR) and Department of Environmental Affairs and Tourism in RSA, respectively.

To realise the objectives of the workshop, the following methods were used in the workshop:

- Presentations;
- Discussions, questions and positive criticism (Nominal Group Technique);
- Charts;
- Role cards;
- Worksheets.

2. RATIONALE FOR THE WORKSHOP

The choice of performing a workshop for gathering data was based on the following advantages:

- The participants work as a group and thus the advantage of pooled judgements is benefited upon;

- Improved communications between the participants lead to better understanding of their respective operations and responsibilities;
- There exists a vastness of ideas, which is not exhibited by other methods, e.g. questionnaires;
- Balancing of individual dominion is achieved; and
- Participants are encouraged to confront issues on a problem-solving basis.

3. OBJECTIVES OF THE WORKSHOP

The objectives of the workshop were to:

a. Establish weighting values for waste management options at primary health care facilities in Lesotho.

b. Establish the objectives of and the roles of each participant in the waste management system of Lesotho.

c. To reach a consensus regarding the definitions of HCW and a PHC facility.

4. WORKSHOP PROGRAMME

The workshop process is summarised in Tables 1 and 2.

Table 1: Programme for the 6th of April 2005

Time	Activity	Responsibility
08h30 – 09h00	Registration	Ts'aletseng Siimane
09h00 – 09h05	Welcome by chair and Prayer	Ts'aletseng Siimane
09h05 – 09h10	Opening speech	Mr Nkuebe Theko (apology)
09h10 – 09h15	Introduction of the project team	Ts'aletseng Siimane
09h15 -09h 25	Introduction of participants	Participants
09h25 – 09h	Presentation: Problem statement	Dr David Rogers
	Presentation: Procedures to obtain solutions to the problem	Dr Alan Brent and Ts'aletseng
	Presentation: The definition of the system, HCW, PHC	Ts'aletseng Siimane

	facility	
10h30 - 10h45	Tea Break	All
10h45 –	Worksheets: Generation on-site	Dr Brent
	Worksheets: collection & storage	Dr Brent
	Lunch	All
	Worksheets: Treatment on-site	Dr Brent
15h30 – 15h45	Tea Break	All
15h45 – 16h25	Worksheets: Disposal on-site	Dr Brent
16h25 – 16h30	Closing remarks	Ts'aletseng Siimane

Table 2: Programme for the 7th of April 2005

Time	Activity	Responsibility
08h45 – 09h00	Registration	Ts'aletseng Siimane
09h00 – 09h05	Welcome by chair and Prayer	Ts'aletseng Siimane
09h05 – 09h10	Recap of previous day's work	Ts'aletseng Siimane
09h10 – 10h30	Worksheets: Collection and storage (central location) + discussions	Dr David Rogers
10h30 -10h45	Tea Break	All
10h45 – 12h00	Worksheets: Treatment at central location + discussions	Dr David Rogers
12h00 – 13h00	Worksheets: Disposal at central location + Discussions	Dr David Rogers
13h00 – 14h00	Lunch	All
14h 00 - 15h30	Way forward: Plenary session	Dr David Rogers
15h30 - 15h40	Final Closing Remarks	Ts'aletseng Siimane

5. PROCEEDINGS FROM THE WORKSHOP

The following points emanated from the workshop participants and facilitators. They have been recorder under the presentations and discussions headings they emanated from.

5.1 Participants' expectations of the workshop

The participants hoped that the workshop would set the grounds for:

- Implementation of the outcomes of the MSc research;
- Deliberations that would help in the formulation of the National HCWM Plans (NHCWMP) of Lesotho;
- Information acquisition for personal enrichment and also to know what other countries like RSA are doing in terms of HCWM;
- The improvement of strategies and policies that need to be formulated; and
- Define the roles and responsibilities within the waste management system.

5.2 Statement of the Problem

Following Dr Rogers's presentation, discussions followed and a consensus was reached regarding what the problem is. The consensus was reached as follows:

- **Waste at clinics is highly infectious** due to its content of sharps, swabs and dressing, which can transmit diseases like HIV/AIDS and Hepatitis B.
- **Policies:**

a. There are no policies to guide responsible HCWM and many institutions hide behind that fact instead of pushing towards the formulation of such policies. Therefore a system can hardly be built at national level.

b. There exists a lack of alternatives (especially infrastructure and technologies) for proper HCWM.

c. A lack of responsibility occurs at remote clinics where sometimes resources are there but are not being used

- **Low awareness:**

a. At many clinics waste is not considered a problem, but has a high potential of affecting whole communities.

b. Most communities have low awareness on the risks of HCW, but yet have close proximity to waste facilities (even sharing of resources).

- **Resources:**

a. Clinics in remote rural areas are under resourced. There is limited funding and often skills.

b. There is an inadequacy of facilities e.g. equipment for the safe treatment of HCW

5.3 Solutions to the problem

The best solution was for waste managers to operate as and within an appropriate system.

The system would be characterised by being:

a. Safe;

b. Achievable; and

c. Easy to monitor for continual improvement and in support of Agenda 21, which advocates for sustainability of the environment, economy and society.

Under this topic, participants were also asked to write the roles they play within the following categories: Policy, Action Plan, Standards, Monitoring, Capacity-building and Tenders. The participants were given colour-coded paper to write on:

Pink: Name and Position

Green: The role that he/she plays in waste management

Yellow: The challenges that he/she faces in his/ her position.

The outcome of this exercise is shown in Table 3.

Table 3: Participants' roles in waste management

Name	Roles	Challenges	Categories of operation
Sebonoang Mots'oari	1. Ensure proper disposal of waste in wards. 2. Procure containers for other waste including general and body fluids. 3. Education of unit staff.	1. Lack of equipment e.g. containers and staff turnover. 2. Lack of guidelines and policy except for universal precautions	1. Waste generation
Tieho Chatsane	1. Training of waste collectors 2. Inspection of HCWM facilities	1. Lack of funds to train waste collectors 2. Lack of human resource to monitor activities of HCWM 3. Lack of equipment for disposal and treatment of HCW 4. Low commitment of administrators to fund HCWM activities	1. Capacity building 2. Monitoring 3. Full Life Cycle
Seipati Lekoeneha	1. Disease prevention and control through proper environmental management	1. Lack of storage, treatment and disposal facilities for HCW	1. Capacity building 2. Monitoring 3. Full Life Cycle
Mosepeli Ratikane	1. Protection of public health by implementing strategies and policies in disease control. 2. Promotion of good health practices/behaviour s 3. Procurement of containers and proper storage for	1. Inadequacy of funds 2. Absence of legislation 3.Inadequacy of knowledge	1. Capacity building 2. Monitoring 3. Full Life Cycle

Name	Roles	Challenges	Categories of operation
	waste		
Thato Williams	1. Collaborates with MoLG and MoTEC for waste management 2. Training of Health workers in managing waste 3.Availing proper containers and protective clothing for health facilities and workers	1. Unavailability of a sound disposal area. 2. Lack of funds for training of health workers on waste management 3. Poor state of present incinerator	1. Capacity building 2. Monitoring 3. Full Life Cycle
Ntsoaki Zwane	1. Training of healthcare workers in waste management. 2. Collaboration with administrators and town clerk to ensure provision of waste handling equipment and disposal site availability. 3. Continuous inspection in the life cycle of the waste and advising on measures	1. Lack of transport to disposal site 2. Resistant to change by healthcare staff 3. Unavailability of proper containers and protective clothing for workers 4. Low awareness on healthcare workers regarding proper waste handling practices	1. Capacity building 2. Monitoring 3. Full Life Cycle
Motsamai Mahahabisa	1. Teaching Environmental Health Assistants on HCWM and other environmental Health issues	1. The deficit between actual practice and ideal theory that is taught to students	1. Capacity building 2. Full life cycle
Moqekele Mohale	1. Management of Junior staff activities in districts 2. Education of healthcare workers and the public on waste management. 3.Advising relevant	1.Changing the perception of the public on HCW 2.Acquisition of resources in the implementation of proper	1. Capacity building 2. Monitoring 3. Full Life Cycle

Name	Roles	Challenges	Categories of operation
	authorities at health care facilities on HCWM	HCWM 3.Formulation of strategies, and policies by relevant authorities 4. Training and monitoring HCW handlers including scavengers	
Mokitimi Thekiso	1.Coordination of HCWM activities within the MoHSW	1. Formulation of non-existent NHCWMP 2. Engaging all stakeholders in government and private sectors	1. Action Plan 2. Strategy 3. Full life cycle
Thabo Ts'asanyana	1. Coordination of environmental issues related to pollution. 2. Facilitating development of policies, strategies, standards and guidelines for pollution prevention	1. Absence of regulatory tools 2. Inadequate infrastructure to monitor pollution 3.Understaffing for timely response	1. Strategy 2. Policy
Leon Ramatekoa	1.Design programmes to curb pollution 2.Monitoring of activities likely to pollute 3. Create awareness on environmental pollution 4. Ensure compliance with standards	1.Lack of cooperation from line ministries 2. Lack of public awareness on environmental issues. 3. Lack of compliance due to the non-operational state of the environment Act 4. Lack of funds to implement planned activities.	1. Action Plan 2. Capacity building

Name	Roles	Challenges	Categories of operation
		5. Low staffing	
Jūrg Oehninger	1. Coordination of infrastructure projects and maintenance in CHAL facilities 2.Planning and execution of renovations and repairs at health centres. 3.Buying equipment for health centres 4. Maintenance at health centres and network at CHAL	1.Waste management priorities keep changing 2. Little time to do many activities, some very urgent and overriding others. 3. Low collaboration with MoHSW. 4. Some of the authorities' opinion is unfounded and difficult to understand	1. Full life cycle of waste
Godfrey Mvuma	1. Formulation of strategies, guidelines, policies and standards in hazardous waste and HCWM in RSA	1. Lack of understanding by political leaders and top government officials on the importance of policy formulation on waste management issues 2. Roles and responsibilities replication among dept of health and environment.	1. Strategy 2. Full life cycle
Refiloe Sethathi	1.Raise awareness on EIA 2. Review EIA reports 3. Monitor compliance to management plan 4. Participate in developing tools related to EIA	1.Lack of operational legal framework 2. Lack of cooperation from line ministries 3. Lack of financial and human	1. Standards

Name	Roles	Challenges	Categories of operation
		resources 4. Lack of commitment to prioritise environmental issues 5. Lack of environmental awareness	

5.4 The definition of the waste management system

The aim of this presentation was to present the views of the team regarding three points and then lead the participants into reaching a consensus on each of the points. The points were:

- The objectives of Lesotho's waste management system;
- The definition of HCW in the Lesotho context; and
- The definition of a rural PHC facility.

The consensus is summarised in the following sub-sections.

5.4.1 The objectives of Lesotho's waste management system

a. Protection of public health with environmental health and occupational health tools.

b. Protection of the physical and socio-economic environment for better health of present and future generations.

c. Sustenance of a waste information system, especially for rural healthcare facilities.

d. Promulgate legislation and regulations and ensure enforcement of such frameworks.

e. Slot in policy for HCWM in rural clinics.

f. Encourage participation of the public and all other stakeholders in HCWM.

5.4.2 The definition of HCW in the Lesotho context

Healthcare waste includes the following categories at rural health facilities:

a. **Sharps:** which include needles, syringes, and blades and can infect through skin puncturing.
b. **Anatomical (placentas):** which are infectious by virtue of containing blood.
c. **Pharmaceuticals:** includes expired or contaminated drugs. These are chemicals and may be toxic.
d. **Packaging and general waste:** These are not risk waste if managed correctly.
e. **Heavy metals:** includes mercury from medical instruments. This is a minute quantity and is rare at rural clinics.

The inclusion of these categories into the definition of HCW at rural clinics required special consideration for their storage, treatment and disposal options.

5.4.3 The definition of a rural PHC facility

A rural PHC clinic has the following characteristics:

a. It is headed by a nursing sister or a nurse clinician.
b. It reports to a district or Health Service Area (HSA) hospital.
c. It provides basic curative and emergency services as well as immunizations and mother and child services.
d. It does not cater for in-patients

5.5 Comparison of options

Using the Analytical Hierarchy Process (AHP), the participants were requested to perform pair-wise comparisons of available/desired options for on site and off-site (central) locations.

- The AHP proved to be difficult to a certain degree for some of the participants who believed a single comparison of all options of a life cycle stage would have sufficed.
- Inconsistent judgements were identified in certain cases and attempts were made to improve the logical consistencies of these comparison sets.

Important points that were raised during the comparison sessions are summarised below:

- There is awareness that pit or open-air burning is not effective in treating HCW.
- Incinerators are required and should ideally be engineered units.
- Present incinerators fail because the operators do not know how to operate them; also maintenance is a big problem.
- Incinerators should reach temperatures of 1000^{o}C and beyond. Participants felt that it is vital to set the country's own standards and not just what organizations like WHO tolerate.
- Some of the technologies that were compared are not in use in Lesotho. However, they may be considered for use in Lesotho.
- National HCWM plans are being formulated and such technologies and the requirement for procedures need to be incorporated.
- Quality of technologies and procedures should not be compromised due to lack of available funding. Planning should be focused on systems that work and are sustainable, rather that on interim-strategies.
- It is advisable to always have a backup alternative at health facilities in case incinerators fail.
- Pit latrines, which are also used for disposal of HCW, are considered to be a controlled dump.

5.6 Way Forward: Plenary session

The group paved the way forward by specifying what they want to see happening to improve HCWM and what is needed to make it happen. Actions were identified as summarised in the following table.

Table 4: Planned goals and activities to improve HCWM in Lesotho

Goal	Main Activity
1. Identify gaps and collect data (or use existing one) to improve healthcare waste management	1.A centre of data excellence (expertise) should exist that will: a) Handle technical issues independently and rationally (meetings). b) Prioritise the components of the waste management system to tackle first. c) Identify training needs and packages. d) Integrate with the NHCWMP (meetings). 2. NES should cooperate with MoHSW, MoLG, MoNR and NGOs to coordinate the implementation of the MSc thesis findings. 3. Management personnel should acquire information and make other relevant persons e.g. maintenance aware of current situation and way forward
2. Assign responsibilities, budgets and commitment to policy for waste management	1. Prepare budgets to fund appropriate equipment
3. Formulate guidelines and procedures for appropriate alternatives.	1. Advocate for the formulation of guidelines and procedures for the diverse professionals that deal with HCWM. 2. Strengthen the capacity of operational staff and professionals by conducting on the job training 3. Discourage the use of open air

	burning to treat waste
4. Develop Job specifications for guideline and procedure formulation and implementation considering “tool box talks”	1. This will be done from recommendations of an advisory committee.
5. Adopt the MSc research into national HCWM plans via pilot project(s)	1. The outcome of the thesis should serve as a waste management survey, giving data of classes of waste and the quantities generated at PHC facilities as well as costs. 2. It is hoped the thesis will come up with options that emphasize risk but strike a balance between capital and operational cost of ESTs and the risk posed to HCW handlers 3. The thesis may also identify a general methodology, which can be used for other problems e.g. industrial waste. 4. Recommendations to be implemented to improve segregation and treatment of HCW
6. Form a committee that will monitor the implementation at healthcare facilities	1. Committee is to help in the formulation of guidelines and get commitment of healthcare facility managers or administrators
7. Promulgate and formulate regulations to control waste management (HCW)	1. Advocate for the promulgation of sound legislation to support NHCWMP
8. Implement inspection of premises	1. Premises to be inspected routinely to ensure application of guidelines and procedures
9. Devise a penalty system for trespassers	1. Penalties to be charged on facilities that still use methods that will be prohibited (open-air burning)
10. A monitoring system should be put in place	1. Monitoring results should be fed back as input to the system so that it can be continually improved.

Finally, it was agreed that the results of this study would be communicated to the participants of the workshop towards the end of 2005.

APPENDIX 3: MODIFIED WORLD HEALTH ORGANIZATION RAPID ASSESSMENT TOOL (TOOL D-1)

Health-care waste management • Rapid assessment tool			**(country)**
Tool D-1	**Interview**	**Manager or deputy of health care facility**	**Duration: 30''**
Health care facility:	Address:	District:	
Name of interviewee:	Function:	Tel. n°:	
Assessment made by:		Date of assessment:	

c	n°	topic	question	type	data	comments / multiple choice
	2	**health care facility (HCF)**				
	200	HCF	Which category is it ?	C		[1] ambulant service; [2] (sub-)district hospital; [3] large hospital
	201	HCF	Which type is it ?	C		[1] public; [2] private
	203	services	which services do you have in your HCF	C		[1] medicine; [2] gynaecology; [3] surgery; [4] children services [5] emergencies; [6] radiology; [7] laboratory; [8] other (specify)
	204	bed capacity	How many beds do you have in total ?	N		
	3	**staff**				
	300	medical staff training	Is training of med. staff available regarding HCWM ?	B		
	301	medical staff training	If yes, what kind of training is given ?	T		
	302	staff for HCWM	Who is in charge of HCWM in your facility ?	T		
	303	training of responsible of HCWM	What kind of training has this person followed ?	T		
	306	medical staff numbers	Could I have a break down of the medical staff ?	B		
< >	**9**	**HCW off-site transport**				
< >	900	transport services	Are there any control measures ?	B		[0] none; [1] transport form; [2] other (specify)
< >	901	type of transport	Who does generally transport the HCW ?	C		[1] the HCF; [2] municipal service; [3] private company (name ?)
	1000	HCW treatment	Is it treated on-site or off-site ?	C		[1] on-site; [2] off-site

	10	**HCW treatment**	*Ask to be allowed to take photos of the system !*			
< >	1001	off-site HCW treatment	Who's in charge with the off-site treatment ?	T		
< >	1002	off-site HCW treatment	Does this organisation offer satisfactory options ?	B		
	12	**HCWM regulations (code of conduct; management plan, policy…)**				
	1203	HCF HCWM regulations	Can we have copies of existing (in preparation) doc. ?	B		
	13	**policy and budget**				
		Funds sustainability	Who is the source of your funds?	**C**		[1]Government; [2]Organization;[3]User-fees;
		Accessibility of funds	Is it easy to access funds from central level?	**B**		
		Signing powers	Who has signing powers over funds?	**C**		[1] District hospital; [2] Organization office;[3]Head nurse
		Budgeting type	What type of budgeting system do you use?	**C**		[1] Zero-based; [2]Incremental
	1301	budget allocation for HCWM	Do you think sufficient funds are allocated to HCWM ?	B		
	1303	budget allocation for HCWM	Which % of the HCF budget do you allocate ?	N		
		Overall spending	What mechanisms do you use to avoid over- and underspending?	T		
		Accountability	How do you account for spent funds?			[1]Audits; [2]Receipts; [3]Reports
		Balancing figures	Is there balancing of figures at the HCF?	B		
		Capital costs	What was the capital cost of current HCW technologies per unit waste?	N		
		Operating costs	What is the cost of running HCWM systems per unit waste	N		
		Cost-saving activities	Do you practice any cost-saving activities?	B		
		Targets for savings	Do you have targets for saving?	N		
	1308	annual report of activities	Could I obtain a copy of your annual report(s) ?	B		try to obtain copies of the last 2-3 years

APPENDIX 4: PILOT STUDY REPORT

MMAMETLHAKE HOSPITAL PILOT STUDY REPORT

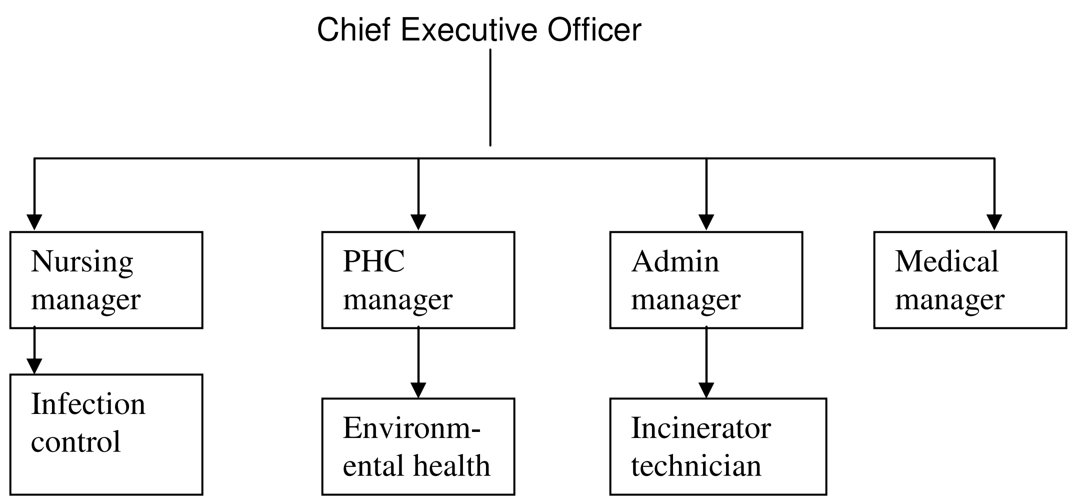
1. INTRODUCTION

Mmametlhake hospital is situated within the Mpumalanga province, within the district of the Nkangala district It is an ambulant and sub-district hospital with 50 beds (improvised to 56), which were fully occupied at the time of the study. The hospital sees between 60 and 70 outpatients per day. The highest level of decision-making lies with the Director General (DG) at national level. The hierarchical representation shows the following:

National level: Director General

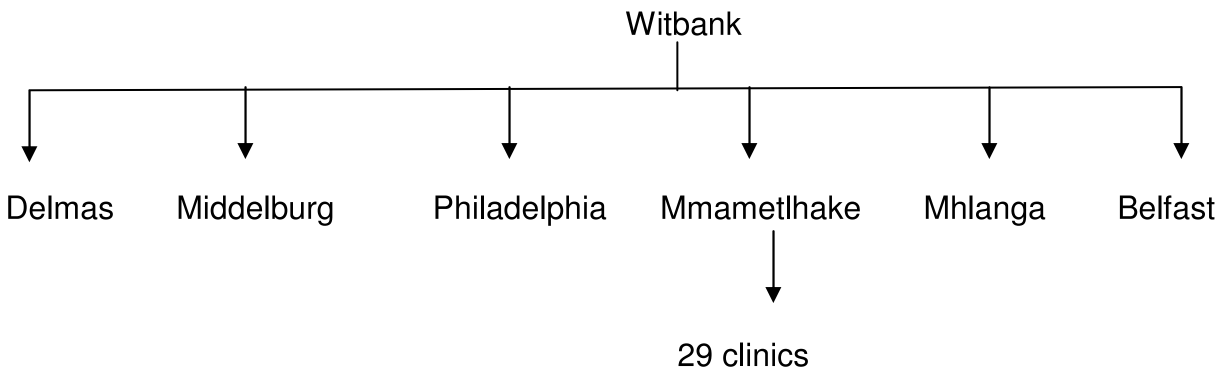
Provincial level: Chief Director

District level:



The CEO is the decision-maker in the hospitals. The district hospital is Witbank hospital and has six hospitals under it as shown below.

District hospital:



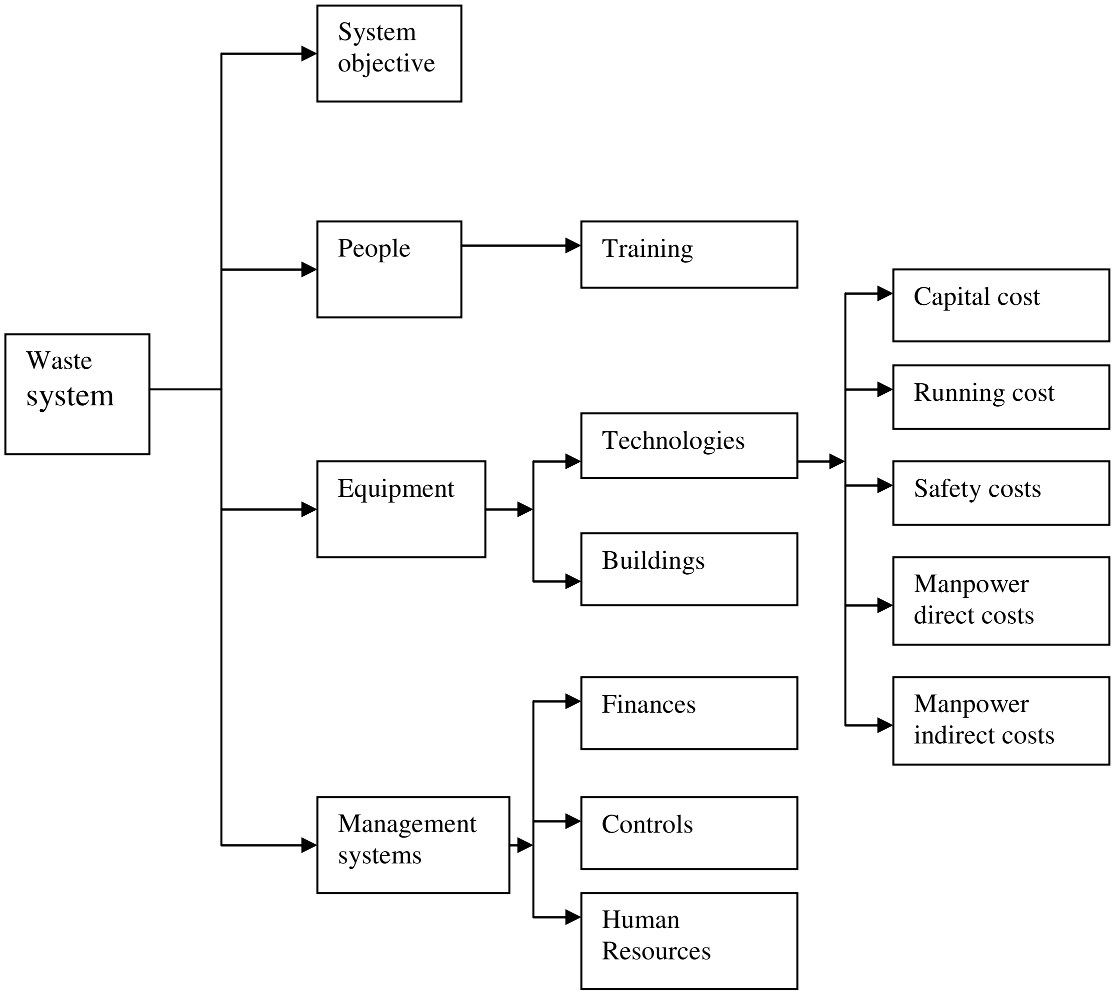
Mmamethlake hospital offers the following services:

Medicine	Gynaecology	Surgery	Children services
Emergencies	radiology	Laboratory	Dental
Maternity	Physiotherapy	HIV/AIDS	Antiretroviral clinic

1.1 The waste system

The systems approach to waste management is based on objectives of the system, people, Equipment and management systems as shown below.

Figure 2: The systems approach to waste management



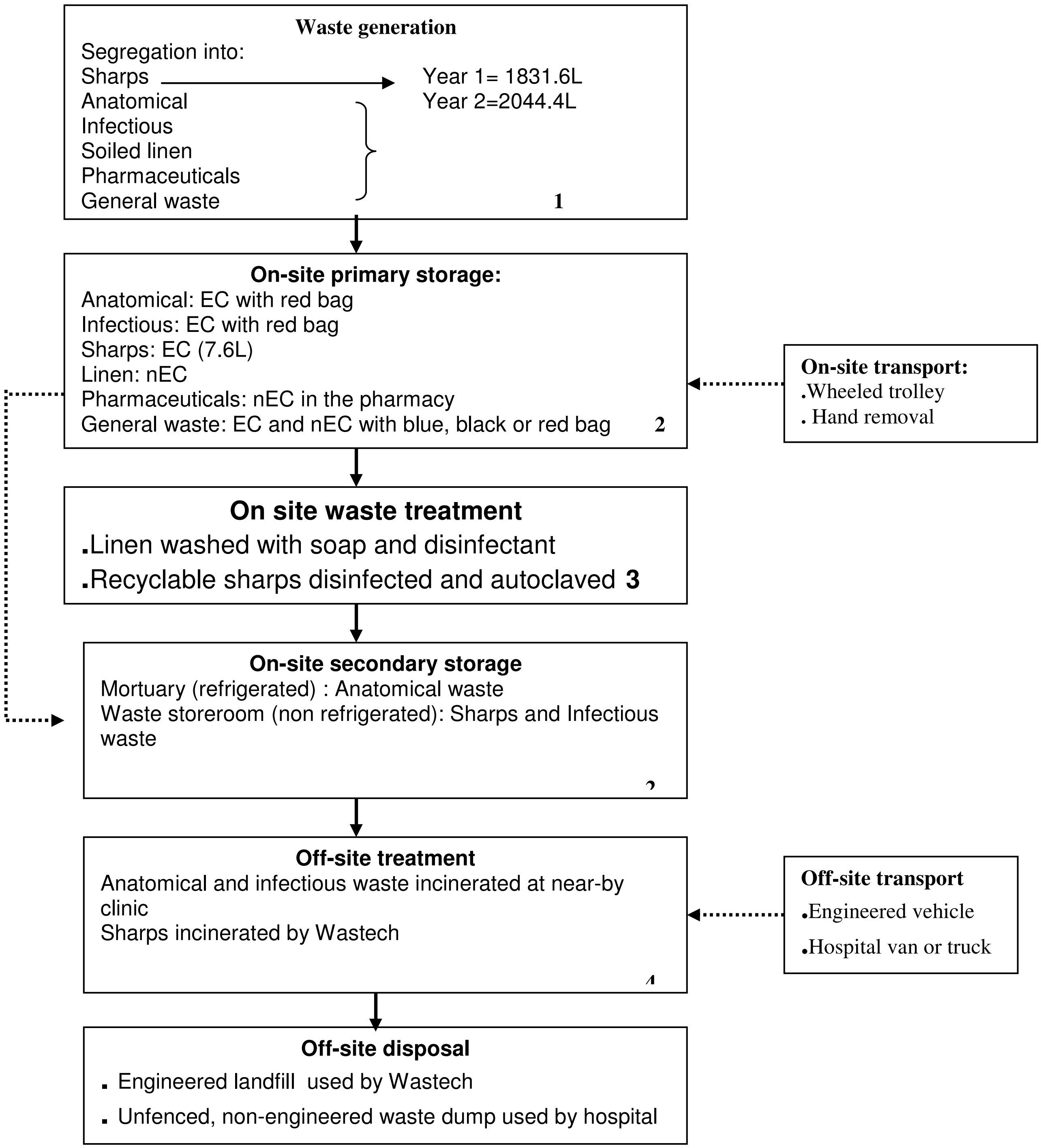
2. OBJECTIVES OF THE STUDY

The general aim of the project was addressed to the problem of providing resource poor decision-makers with a practical tool to identify and prioritise options to reduce impacts on the public and healthcare workers resulting from the management of hazardous waste generated at healthcare facilities. This would be realised by performing the following tasks:

- Qualify and quantify within each class the HCW generated by classification
- Device a mass flow of commodities and waste within the hospital system
- Analyse the waste system in place at the HC facility

3. FINDINGS AND OBSERVATIONS

3.1 Waste Flow Diagram (figure 3)



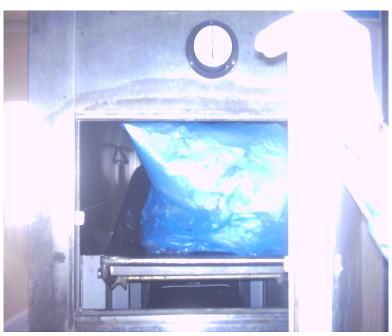
The flow chart above pertains to the responses given by health professionals at the hospital and have been presented in a life cycle approach. The life cycle is also shown in pictures below Table 1 below shows figures of waste generated within the facility

1. Storage at generation point in ward

2. Storage at generation point

3.temporary storage

Trolley for primary transportation



Anatomical waste in mortuary

Sharps in storeroom

Out of order incinerator

Waste stored outside storeroom

Table 1: waste generation figures

Life cycle stage	Reference no.	Amounts of goods/waste
Goods supply for 1 month Swabs gauze (8ply x 100x100mm) Dressing gauze(100mmx7m) Alcohol swabs(24mmx30mm) Disposable hypodermic syringe Hypodermic needle Bandage cotton crepe(150mmx4.5) Bandage cotton crepe(100mmx4.5m)	Not within the waste flow diagram	372 packs@100 units/pack 27 packs @1 unit/pack 129 units 5 Units 13 packs@ 100 units/pack 64 packs @12 units/pack 61 packs @ 12 units/pack
Waste Generation Sharps Anatomical Infectious Soiled linen Pharmaceuticals General waste	1	Year 1=92 boxes x 7.6L =599.2L Year 2=119Boxes x 7.6L =904.4L 4 bags in 8 weeks No data No data No data No data
Waste storage	2	Non-quantified sharps stored for 1 year
On-site treatment	3	Recyclables not quantified
Off-site treatment	4	Contractor has not collected in one year. **No data**
Disposal	5	Contractor has not collected in one year. **No data**

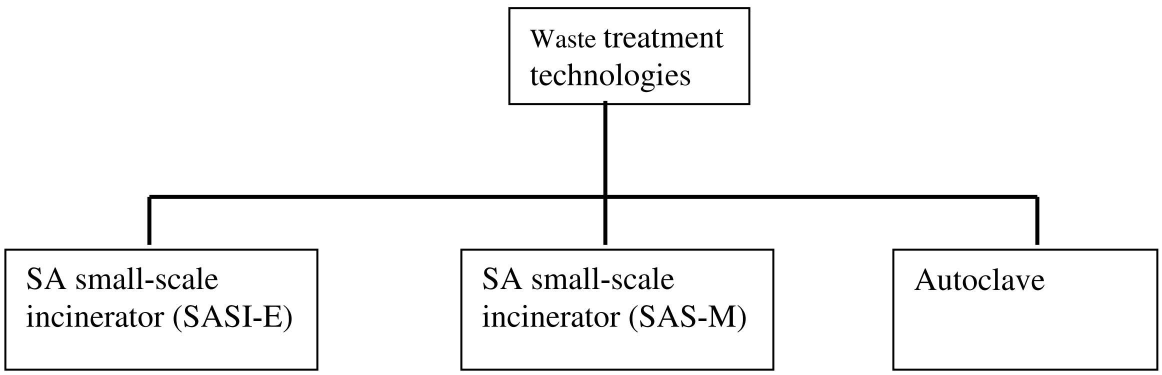
From the table above:

- Goods supply is for a single ward for one month. This can not be safely extrapolated to daily or annual amounts because of changes of disease patterns with season and differing bed occupancy.

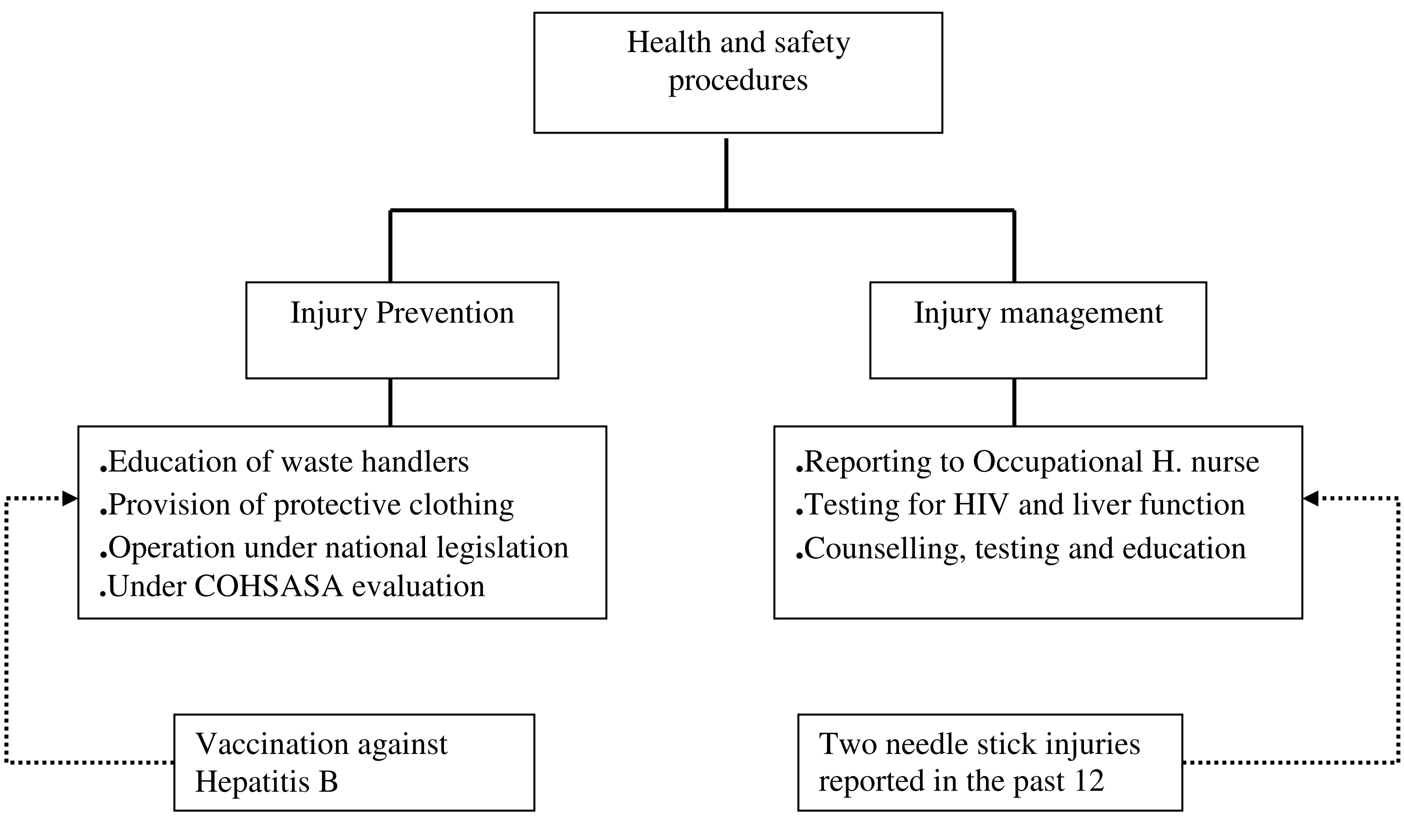
- Sharps stored were full in the storeroom and could not be counted. Records of up to September 2004 are present. Also sharps are collected from other clinics and their disposal is incurred by the hospital.

3.2 Technologies and procedures

Technologies



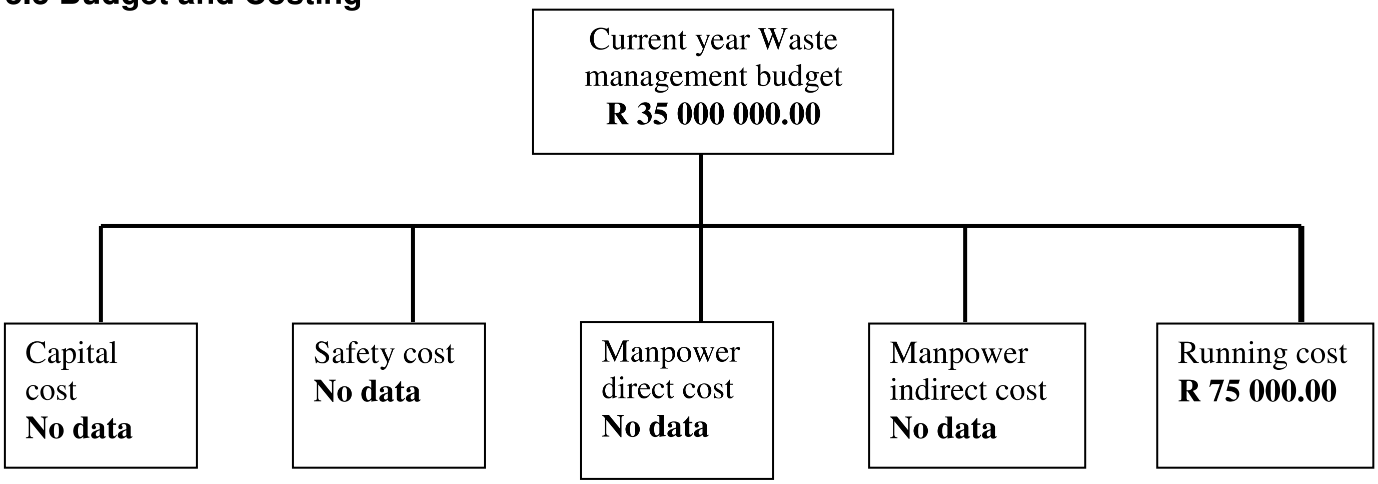
Procedures



The hospital also uses the following guidelines

- Guidelines for disposal of needles, syringes and sharps (provincial)
- Needle stick injury policy (July 2004)
- Waste management policy (August 2004)
- Colour coding of bags

3.3 Budget and Costing



- The amount of R35 000 000.00 is budgeted for packaging and this includes sharps containers purchasing, transportation and treatment and disposal by the private contracted company.
- Only R75 000.00 (0.21 %) had been used up to the time of the study for sharps emanating from the hospital and all the 29 clinics.

4. PROBLEMS ENCOUNTERED

- Mass of waste generated was not established due to the absence of a usable balance.
- Due to the rainy weather and absence of transport, waste flow was not followed up to the municipal waste dump.

5. INTEPRETATION

A life cycle approach to waste management ensures that all aspects of waste are taken care of since they are inter-related. Life cycle Assessment is however too extensive a tool to use for WM in developing countries and is not appropriate to use at sub-national levels of operation. Wasteopt comes in as a tool that can be used from policy-making to implementation stages of waste management.

WasteOpt encourages:

- The use of life cycles of the waste management process such that waste is managed from “cradle-to grave”. Mmametlhake hospital is aware of the life cycle management and environmental, top management, occupational health and infection control staff all work together to achieve proper waste management.
- The identification of options within each stage that can minimise risk at a reasonable cost. A good budget is in place for waste management in the hospital. It is however not easy to engage in waste management due to it being tied to packaging. It could benefit waste management if the budget could be separated in the future. This can then enable such needs as protective personal clothing and fixing or purchasing of an incinerator possible.
- It is also possible through WasteOpt, to assess the benefits of transportation to a central location for treatment and disposal compared to fixing old incinerators or buying a new one. This would need also the inputs of cost modelling and feasibility assessment.
- Hierarchical trees incorporate procedures and equipment, which make technologies environmentally sound. The hospital has written procedures on needle stick injury and colour coding of bags. Procedures should be present also regarding the sustainable use of human resources such that top management does not order untrained personnel to deal with waste management.
- Hospital personnel are aware that a risk exists when dealing with waste, although it is not quantified. The application of WasteOpt can give ranking of technologies and procedures in terms of risk.

The data that was compiled in this study can not facilitate the complete application of WasteOpt to this hospital.

6. RECOMMENDATIONS

6.1 Waste Storage

- The colour coding of bags should be strictly adhered to. This decreases the risk to handles and makes colour coding worthwhile.
- Sturdy engineered waste receptacles should be provided
- Waste storeroom must be lockable and is best refrigerated such that the mortuary is used for the intended purpose.

6.2 Waste Collection

- It could be ideal to contract a waste removal company that collects waste more frequently (as opposed to the current once in 13 months)
- Staff should be encouraged to use trolleys for on-site transport to decrease the risk of falling and or bag tearing with weight.

- The on-site SASI-E has been proven (CSIR and Mmametlhake hospital) to be very efficient in destroying pathogens and in fuel use. The hospital should consider fixing it to reduce cost of transporting to another clinic.

6.4 Waste Disposal

- The municipal dump personnel should not accept any untreated healthcare risk waste.
- The hospital should put pressure on the municipality to fence the dump.

6.5 Staff Issues

- All waste handling personnel without knowledge on waste management should be offered in-house training on HCWM.
- Appropriate personnel should be hired and trained on operating the incinerator such that the mortuary attendant can be efficient in his area of expertise.

6.7 Costing and Budget

Future budgeting for waste management should be separated from other aspects of spending so that management can improve and possible savings can be assessed.

APPENDIX 5: DEFINITIOION TO ABBREVIATIONS USED IN THE RESEARCH

GENERATION

- **Engineered Container (EC),** which is puncture-proof, spill-proof, stable, easy and fast to use, and of the appropriate size as stipulated by the WHO and UNICEF guidelines.
- **Non-Engineering Container (nEC),** which does not conform to any one of the technical specification for an Engineered Container.
- **Engineered Location (EL),** which renders the waste secure, but is in easy reach with safe access in terms of infection risks.
- **Non-Engineered Location (nEL),** which does not correspond to these technical specifications.

- **Detailed Procedures (DP),** e.g. sharps handling, etc.
- **No Procedures (nP),** i.e. no specific procedures in terms of best practices are stipulated at the primary health care facility.

COLLECTION AND STORAGE

- **Engineered Wheeled (EW),** i.e. a trolley, cart or wheeled container that is easy to load and is dedicated for waste collection inside the clinic, has no sharp edges, is easy to clean, and is impermeable to sharps.
- **Engineered non-Wheeled (EnW)**, i.e. a dedicated non-wheeled container that is easy to load, has no sharp edges, is easy to clean, and is impermeable to sharps.
- **Non-Engineered non-Wheeled (nEnW)**, which does not conform to any one of the abovementioned technical specifications.

- **EC>EC**: Transferring between Engineered Containers (as stipulated above).
- **EC>nEC:** Transferring from an Engineered Container to a non-Engineered Container, i.e. a container that does not meet any one of the EC specifications.
- **nEC>nEC:** Transferring between non-Engineered Containers.

- **nEC>EC:** Transferring from a non-Engineered Container to a dedicated Engineered Container that meets all of the technical specifications for handling health care waste.

- **Refrigerated Engineered Facility (REF**), where the floor is impermeable, has water supply for cleaning and good drainage, is easy to disinfect, is accessible for staff with good lighting, but lockable, with no direct sunlight, isolated from vermin with passive ventilation, and separated away from food handling areas and patients. Furthermore, the facility has access to Personal Protective Equipment (PPE) for the clinic staff and adequate waste containers.
- **Non-Refrigerated Engineered Facility (nREF**), which, except for refrigeration, has similar technical specifications to a REF, but with a waste turnaround of less than 24 hours in summer, and less that 48 hours in winter.
- **Non-Refrigerated non-Engineered Facility (nRnEF),** which does not meet any one of the above specifications.

ONSITE TREATMENT

- **South African small-scale incinerator, which is engineered (SASSI-E)** and corresponds with the following appropriate technical specifications: 10 kg/d waste-handling capacity, temperatures in excess of 650 °C; single chamber with a chimney.
- **South African small-scale incinerator (SASSI-M),** which adheres to the minimum requirements as stipulated by the national Department of Environmental Affairs and Tourism (DEAT): temperatures between 300 and 400ºC with; static grate, single chamber (confined burning in a drum or brick structure), optional support fuel.
- **Open Air Burning (OAB),** i.e. the last resort in South Africa where no other treatment option is possible; preferably in a disposal pit (support firing not necessary).
- **Engineered Waste Transport (EWT**), i.e. a trolley, cart or similar dedicated wheeled container that is easy to load, has no sharp edges, is easy to clean, and is impermeable to sharps.

- **General Transport (GT),** i.e. another wheeled transport mechanism that is not dedicated for health care waste, e.g. a wheelbarrow.
- **Inappropriate Transport (IT):** i.e. which is not suitable for health care waste in terms of good Environmental, Health and Safety (EHS) practices, e.g. a general waste drum.

- **Engineered Storage (ES),** i.e. a designated storage area of appropriate size, which is secure, lockable, scavenger free, and cool or out of direct sunlight.
- **Non-Engineered Storage (nES),** e.g. inside a small-scale incinerator.

ONSITE DISPOSAL

Engineered pit: An all sides lined pit for disposal of waste.(Often used for sharps.

Controlled dump: A fenced and controlled non-engineered (not easy to access) area for waste disposal.

Open dump: An unfenced, uncontrolled area where waste is indiscriminately disposed

OFFSITE TREATMENT

- **Engineered wheeled vehicle (EWV):** a vehicle that is easy to load, has no sharp edges, is easy to clean, and is impermeable to sharps, dedicated to transport healthcare waste.
- **General vehicle (GV):** another wheeled transport mechanism that is not dedicated for health care waste
- **Inappropriate vehicle (IV):** which is not suitable for health care waste in terms of good Environmental, Health and Safety (EHS) practices

- **MCI (Multi Chamber Incinerator):** DEAT approved; 0.2 to 10 tons per day., 800 – 900 °C / 900 – 1200 °C, gas cleaning for large facilities, water / dust / ash management
- **SCI (Single Chamber Incinerator):** DEAT approved; 0.2 – 1 tons per day. (WHO small) or 50 kg – 1 tons per day. (SA large), air / temp / loading control, 300 – 400 °C.

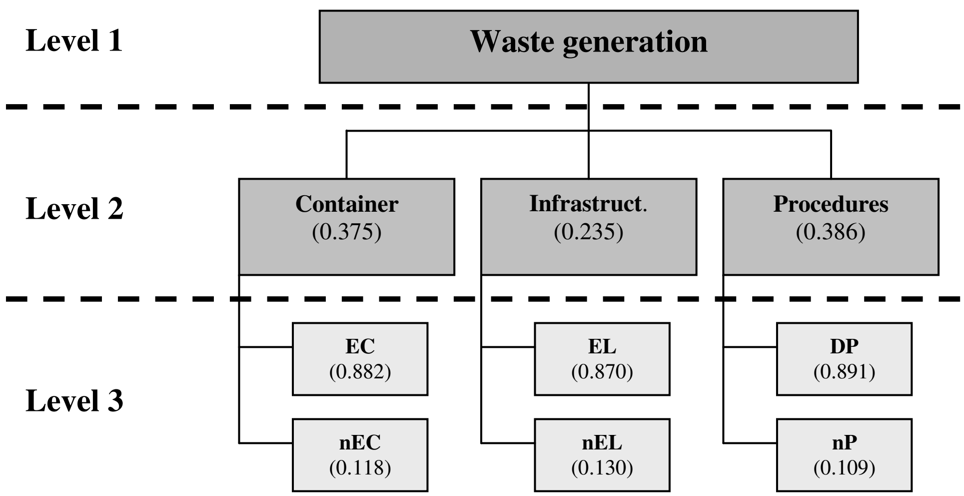
OFFSITE DISPOSAL

Landfill (LF): Operation where waste is compacted and covered with soil daily. Liners present at the bottom for leachate management. Gases emanating are also managed.

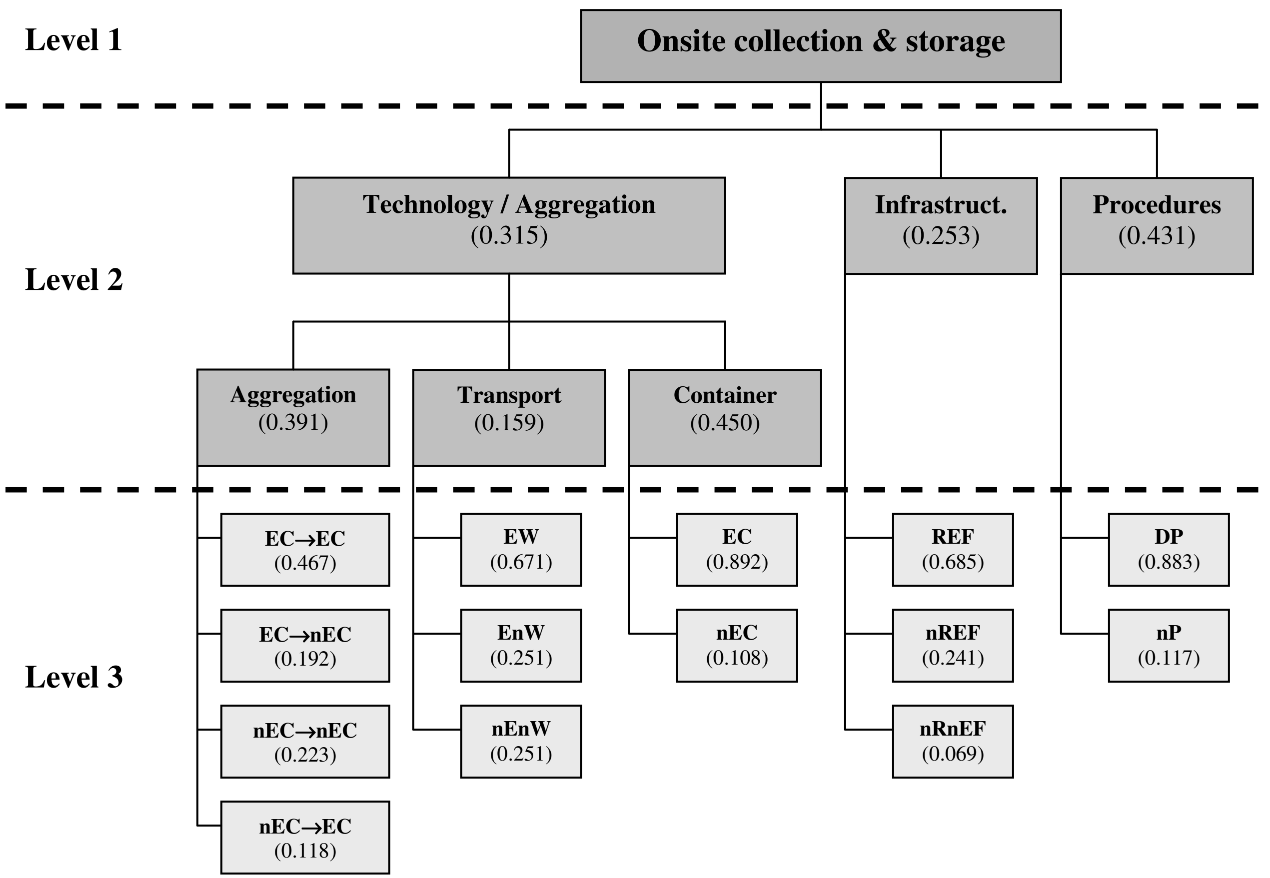
Controlled dump (CD): Authorized entry area with controlled tipping cells designated per period of operation. No compaction, soil and liners applied.

Open dump (OD): Uncontrolled disposal of waste in an open area accessible to anyone.

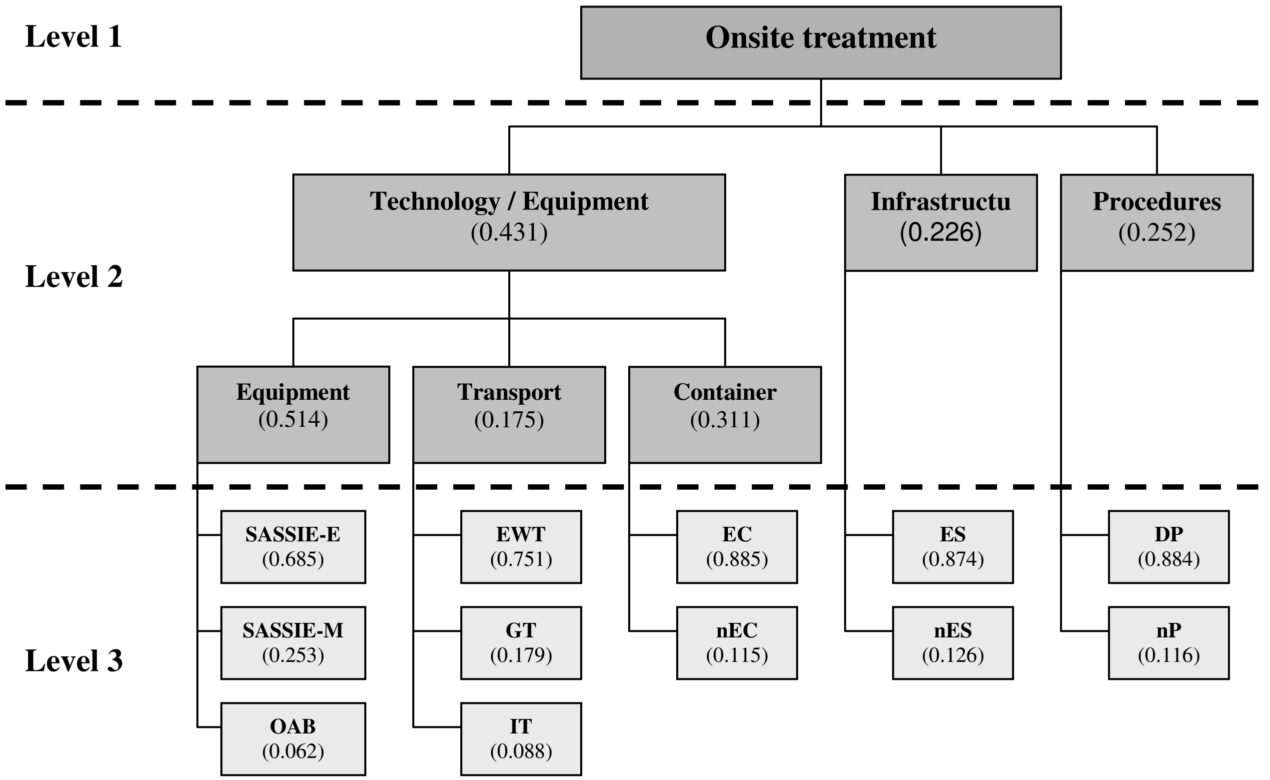
APPENDIX 6: HIERARCHICAL TREES FOR LIFE CYCLE PHASES



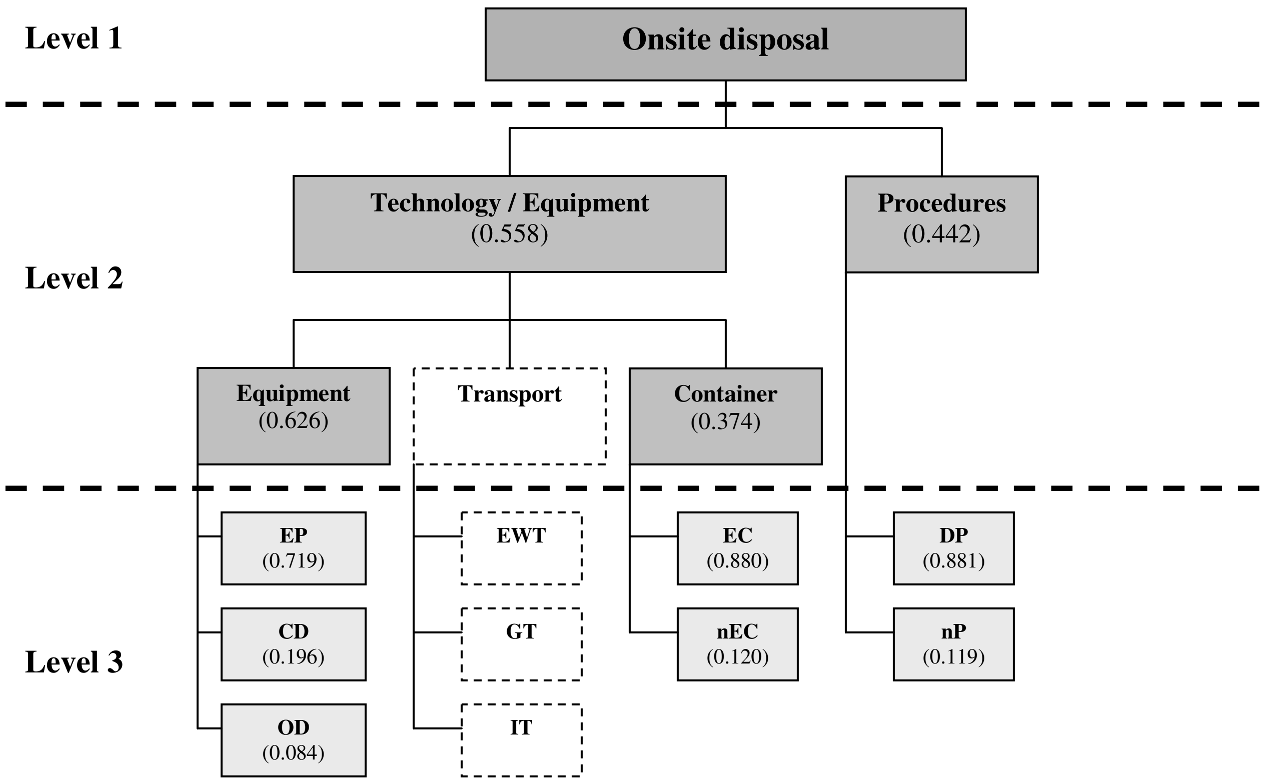
Options for the waste generation life cycle phase



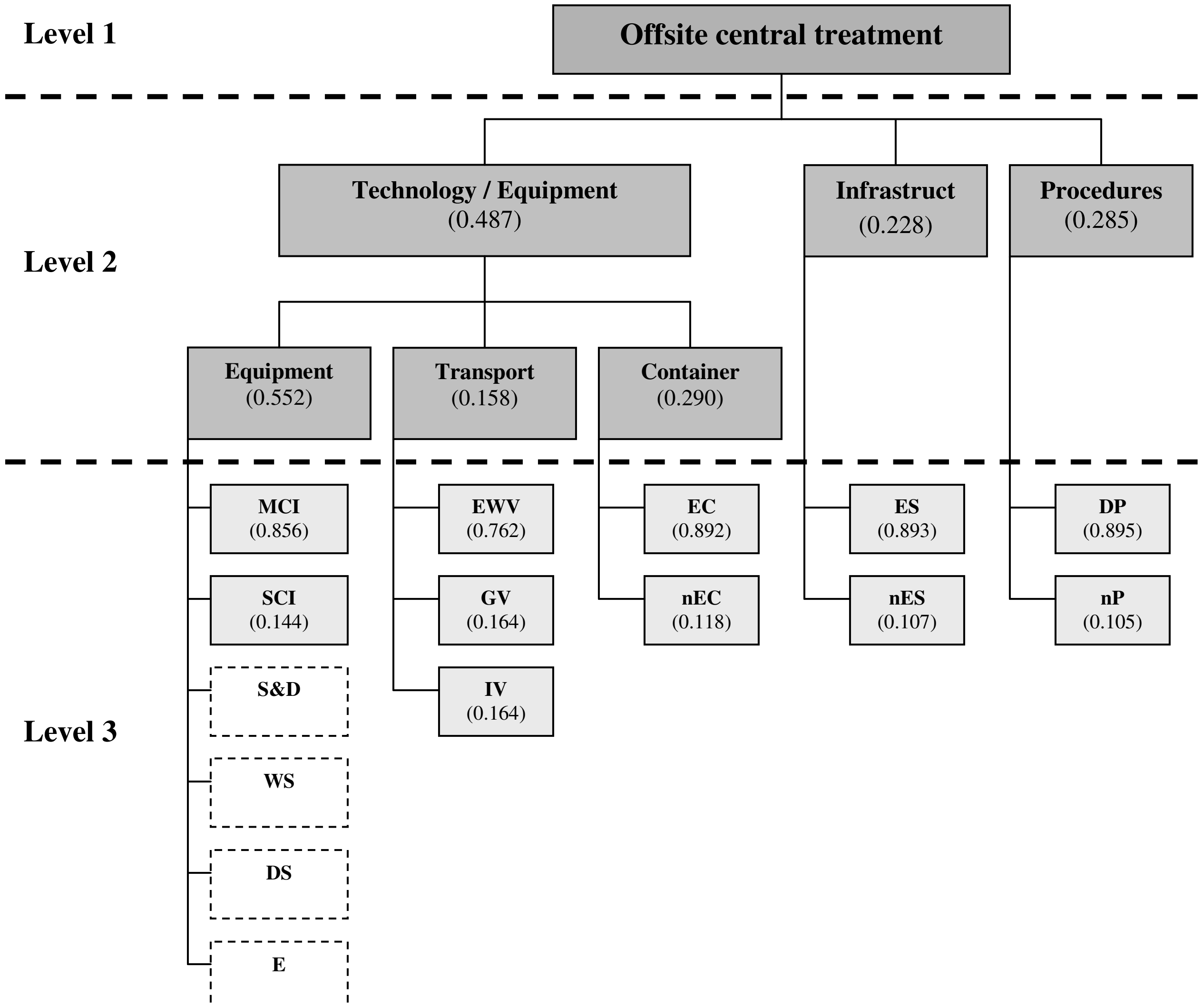
Options for the onsite collection and storage life cycle phase



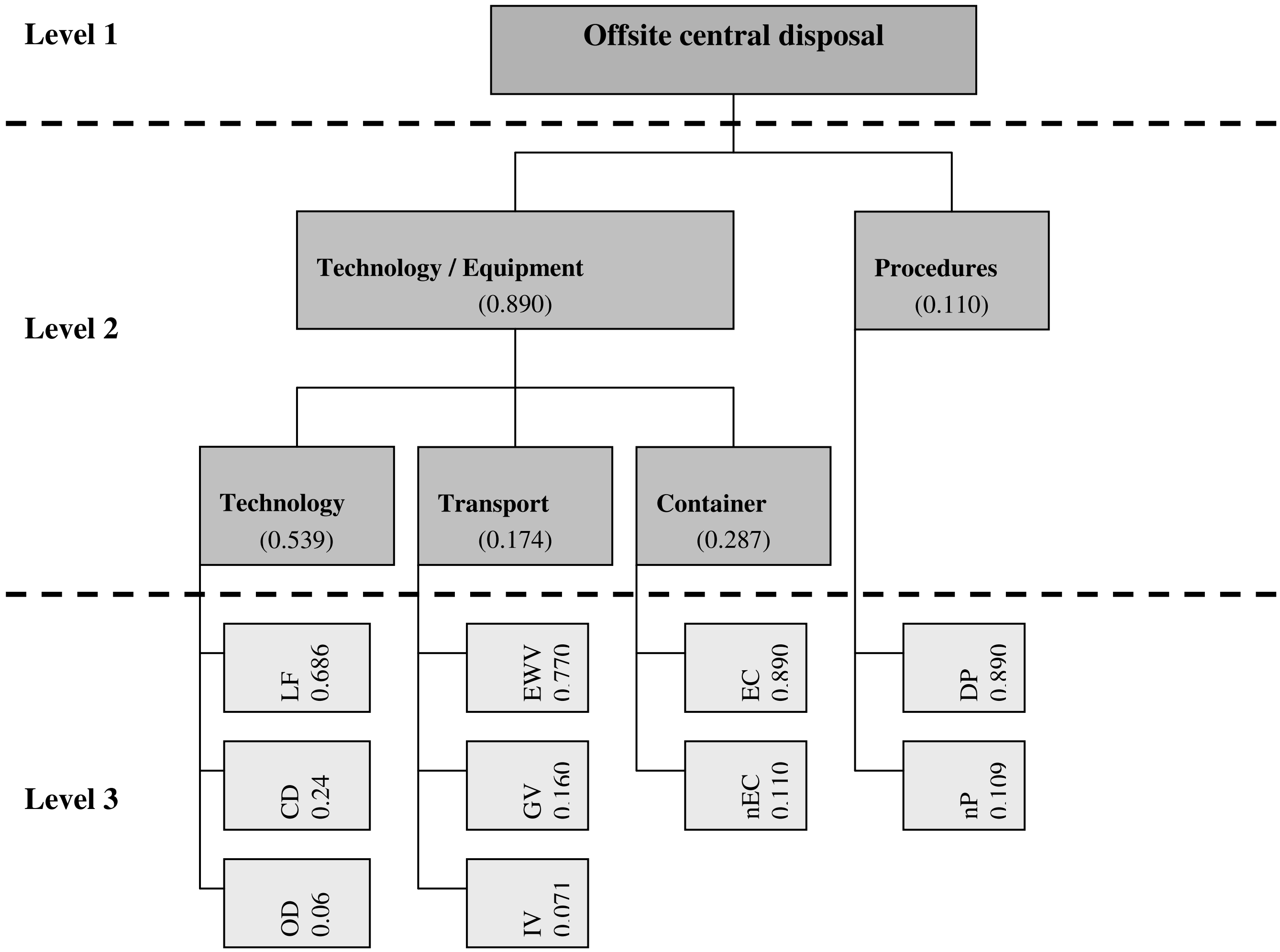
Options for the onsite treatment waste life cycle phase



Options for the onsite disposal waste life cycle phase



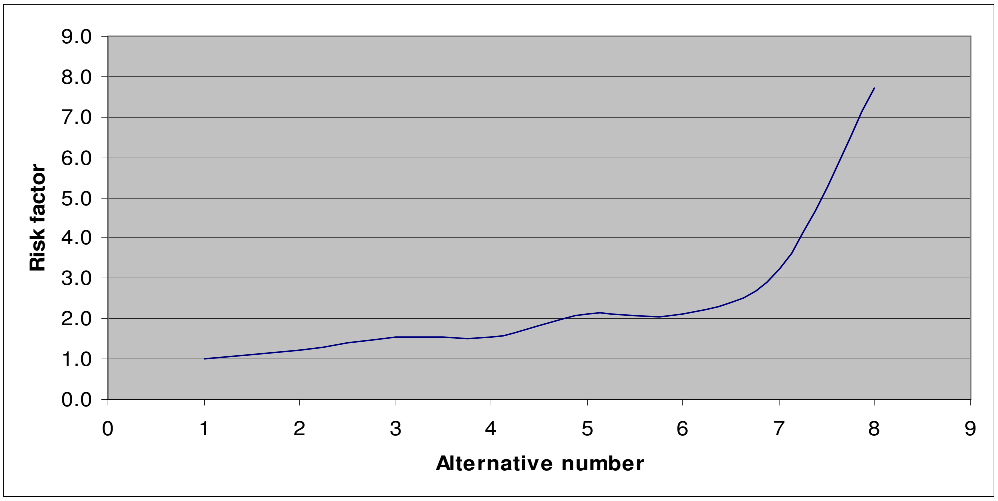
Options for the offsite central treatment waste life cycle phase



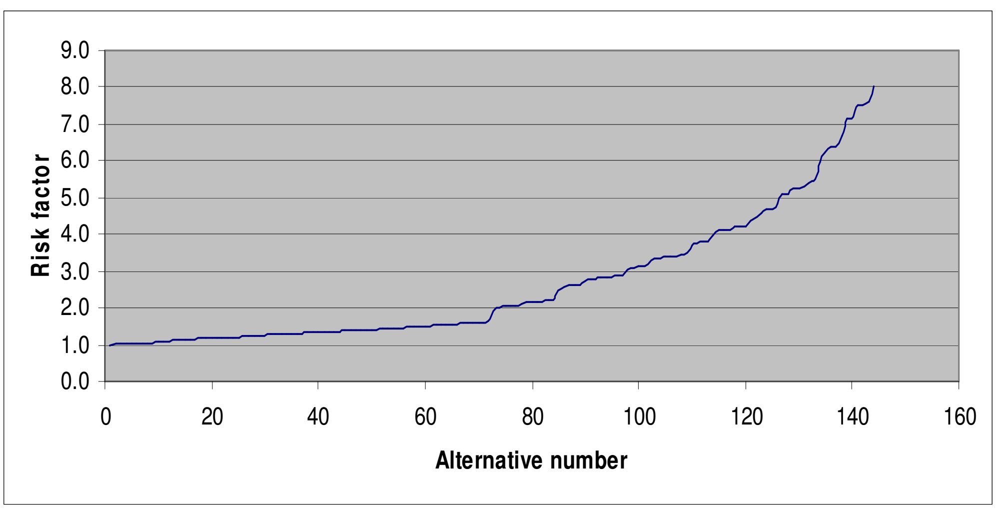
Options for the offsite central disposal waste life cycle phase

APPENDIX 7: MEAN VALUE PROFILES OF AHP RESULTS

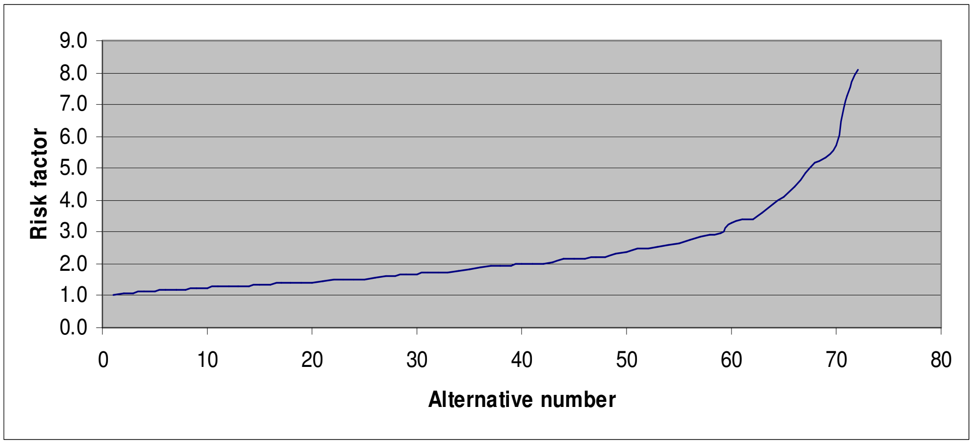
Generation



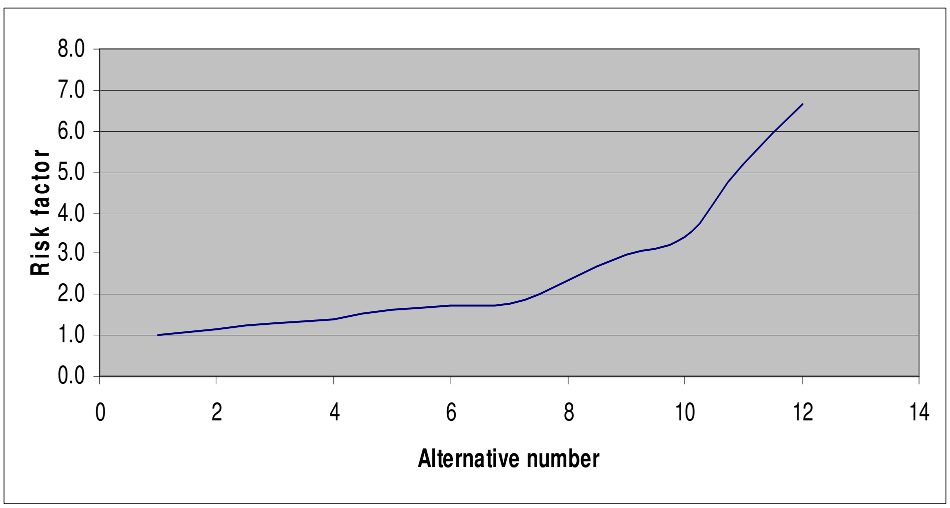
Collection and storage



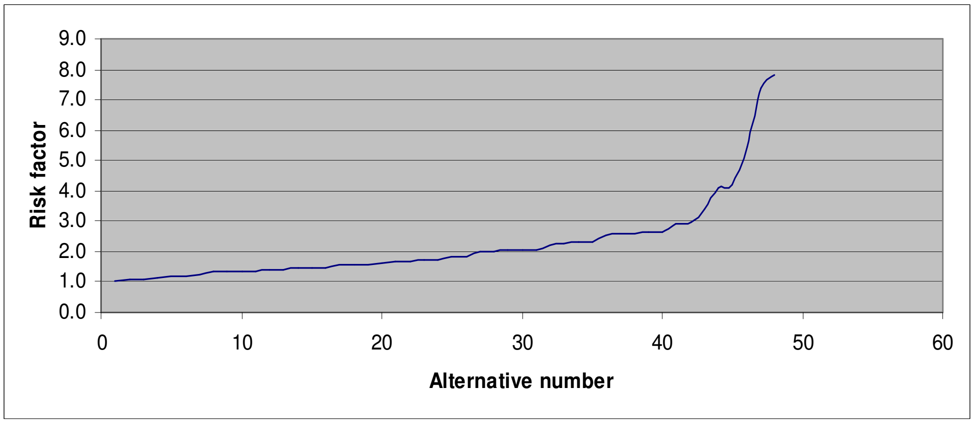
Onsite treatment



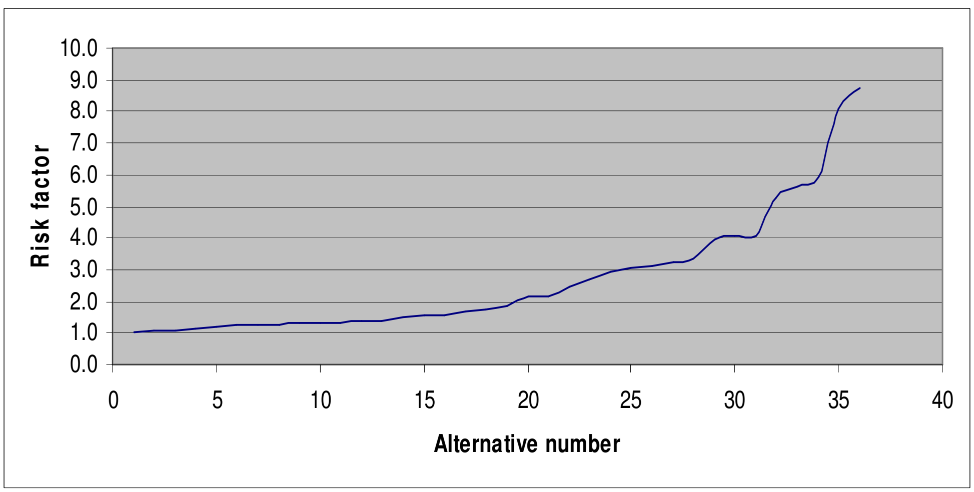
Onsite disposal



Offsite treatment



Offsite disposal



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APPENDIX 8: CONTACT DETAILS OF COMPANIES CONSULTED FOR COSTS

Reco
270 Soutter Street
Pretoria West
Tel: (012) 327 3186

Saubtech
Andrias Thieme
(011) 794 8798

The Waste group
P.O. Box 314
Bon accord 0009

http:// www.nwims.co.za

Lesotho National Healthcare Waste Management Plan