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 <u>underlining</u> 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.

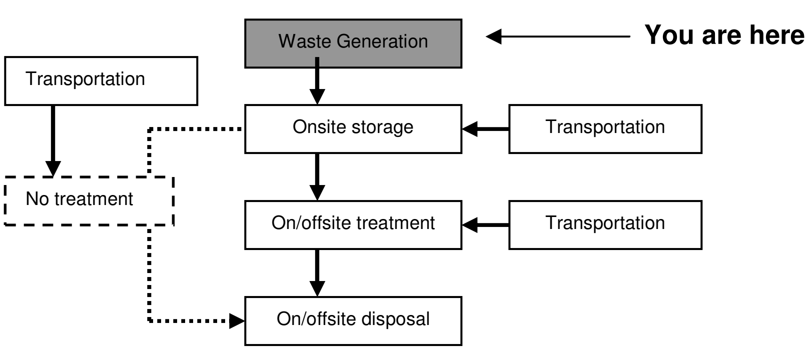
Table 5.2: Calculated risk factors for the choice of options in each component of the life-cycle phases

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.

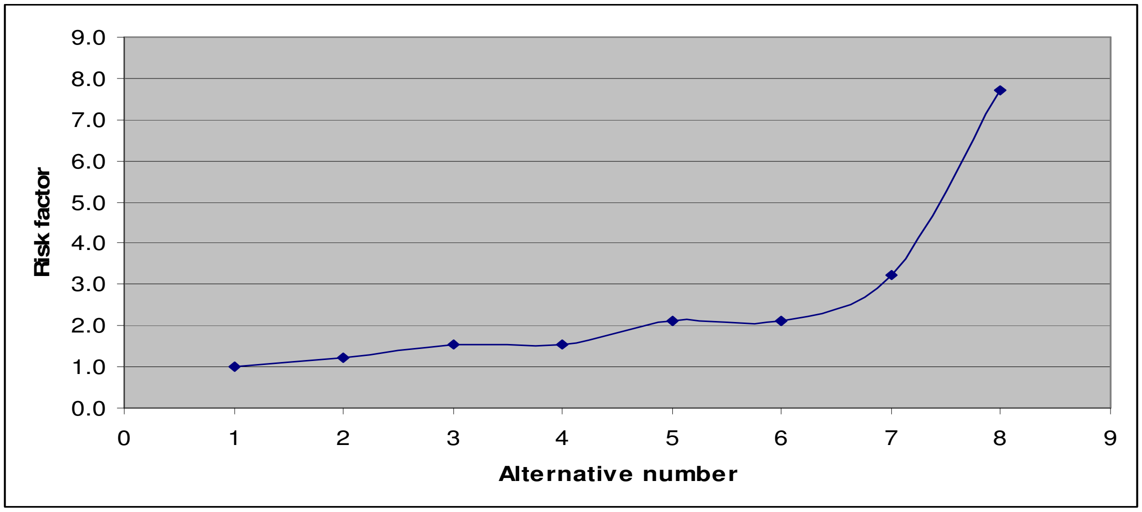


Figure 5.1: Alternative-risk profile for the generation phase

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).

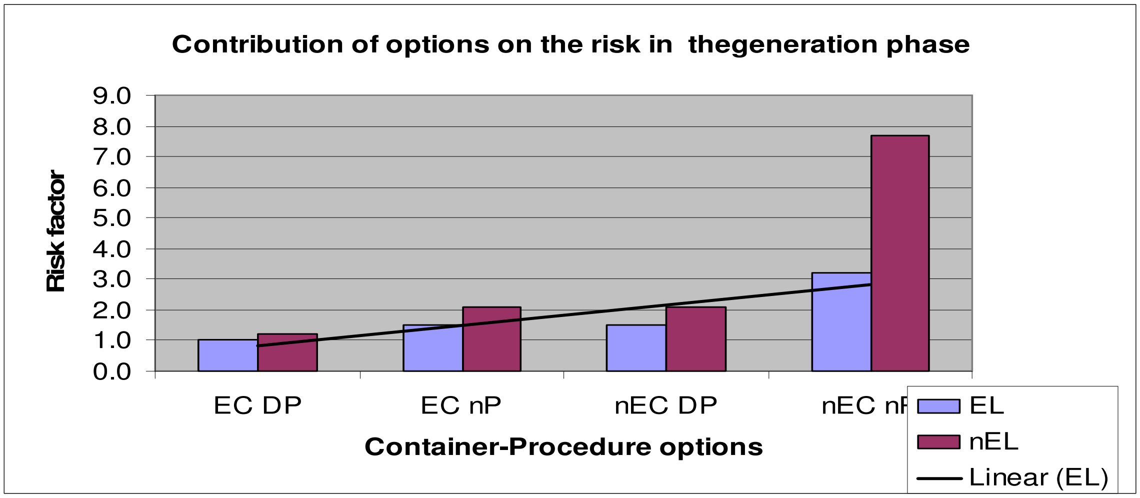


Figure 5.2(a): Graph of risk factors of container-procedure combinations with engineered location and non-engineered location options

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**.

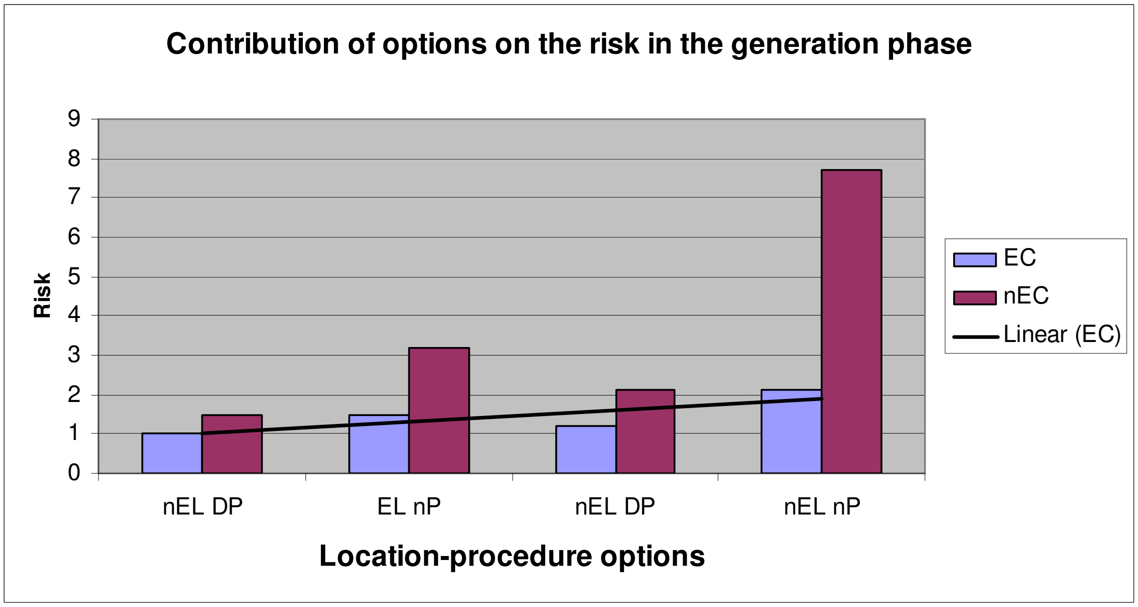
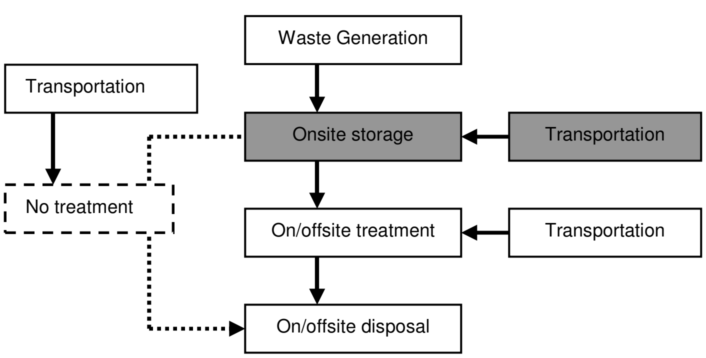


Figure 5.2(b): Graph of risk factors of location-procedure combinations with engineered container and non-engineered container options

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.

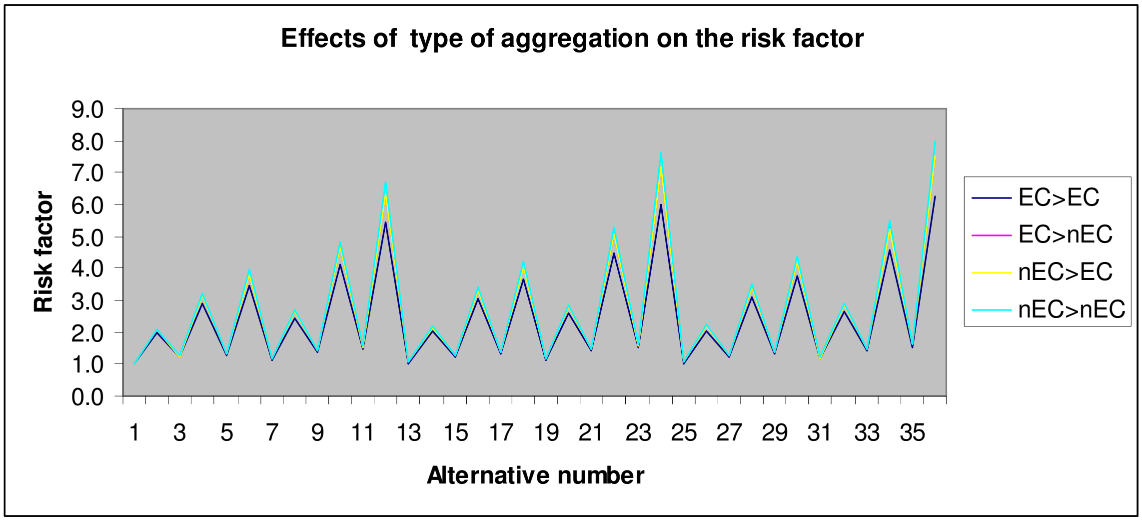
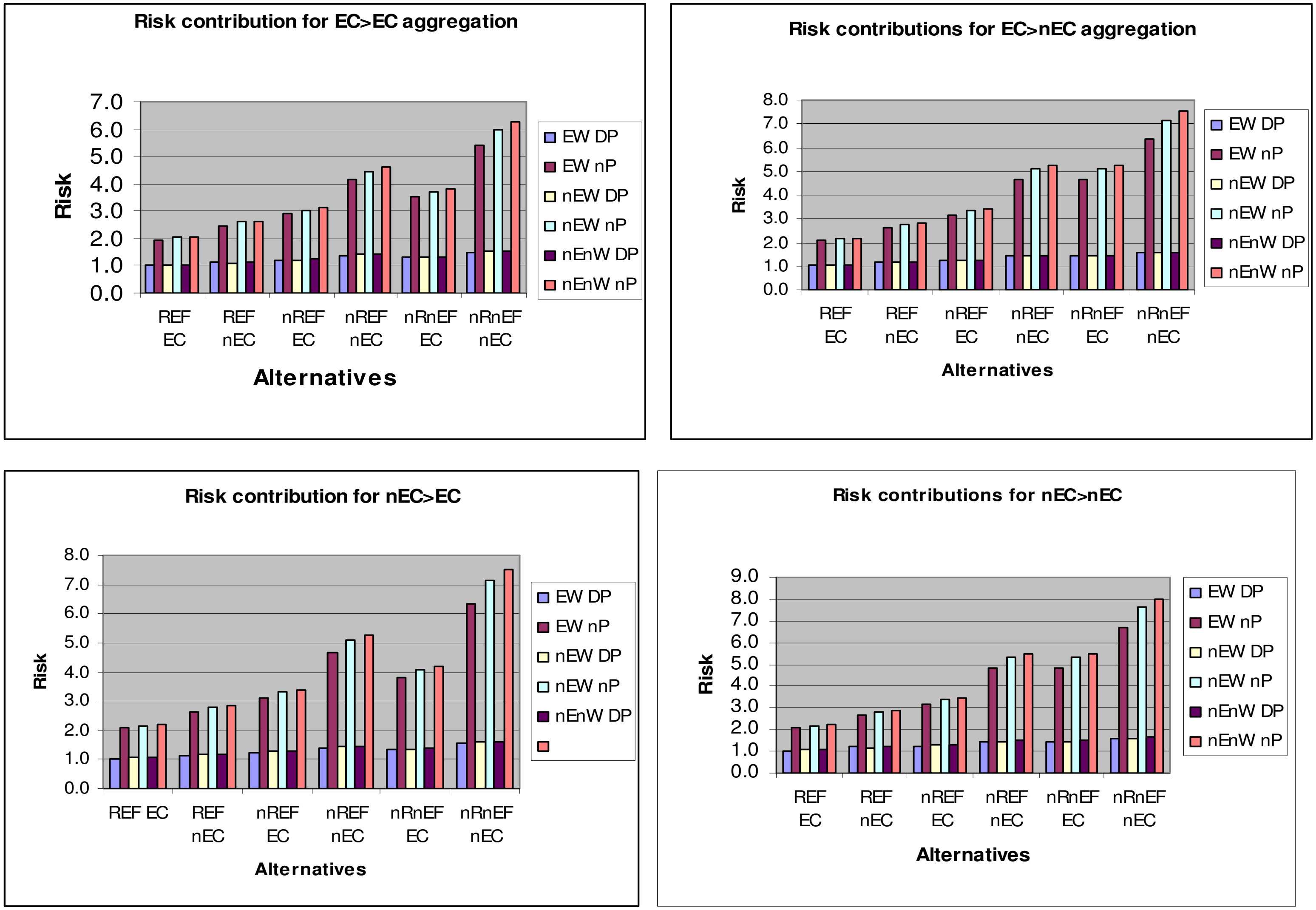


Figure 5.3: The effect of aggregation type on the risk factor for different alternatives

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

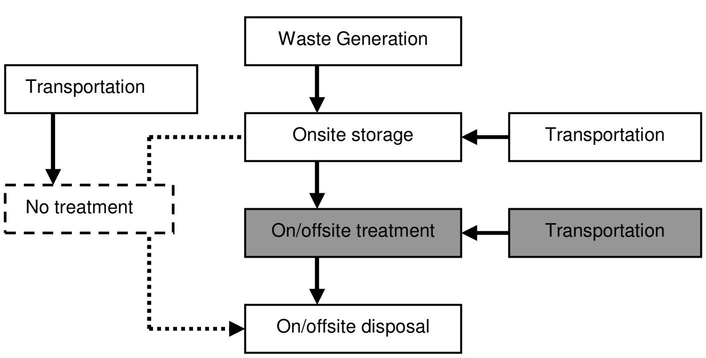
Overall analysis

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.

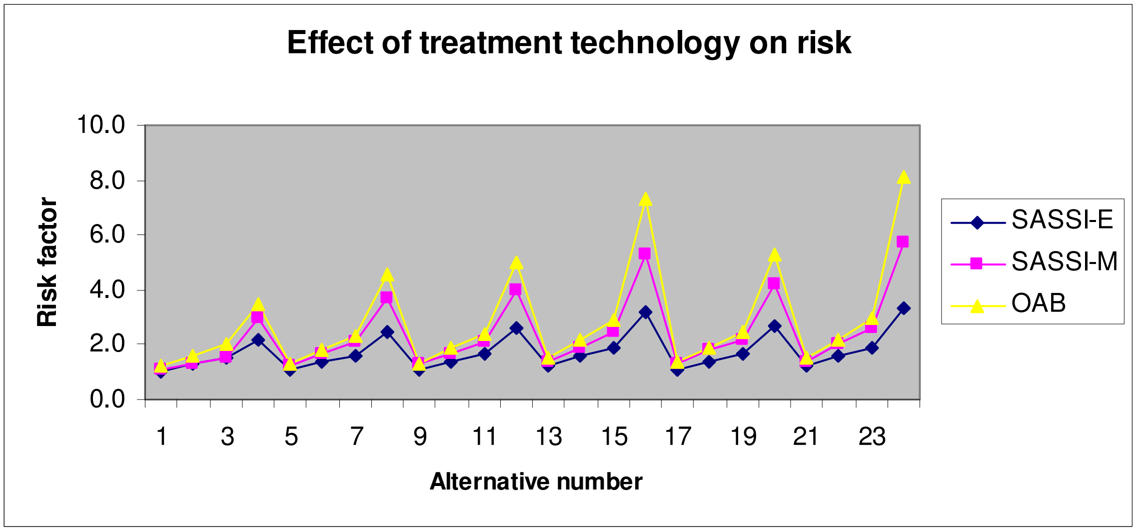


Figure 5.5: Effects of technology variation on risk

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.

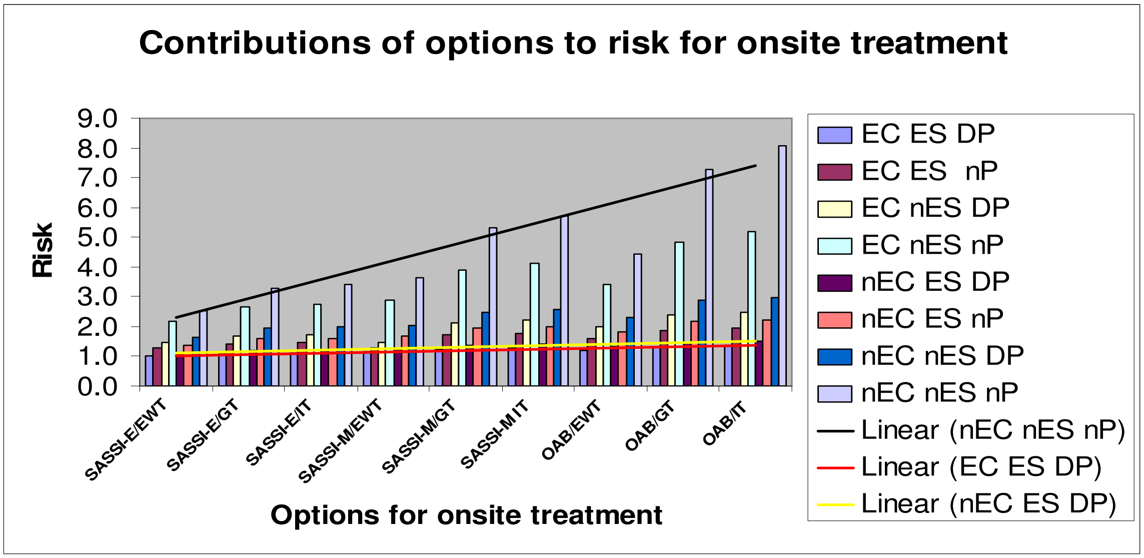
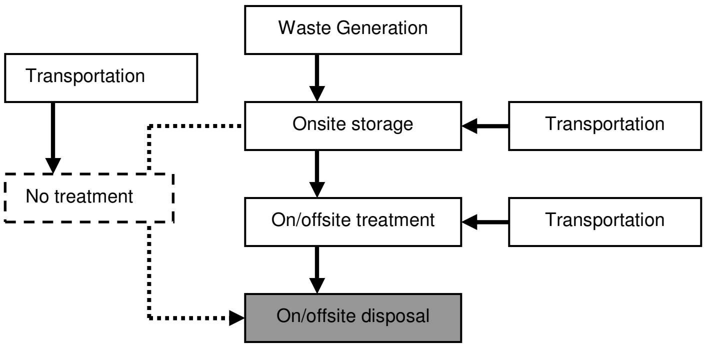


Figure 5.6: Contributions of options to risk for on-site treatment

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.

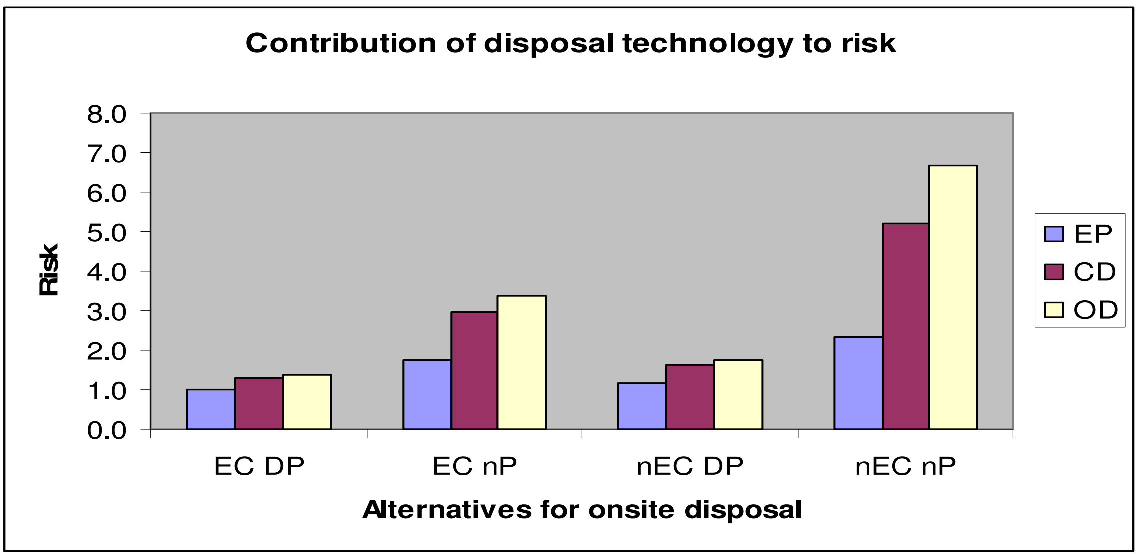


Figure 5.7: Contribution of disposal technology to risk

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

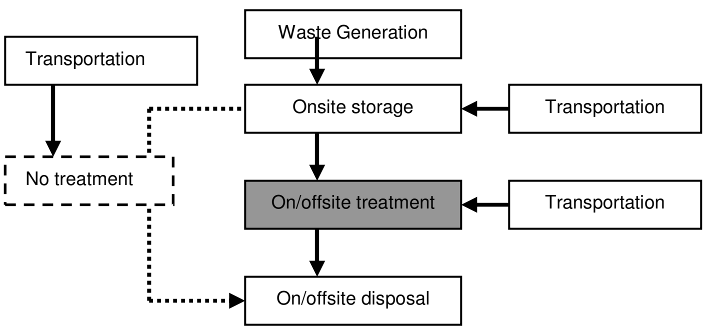


Figure 5.8(a) is the result of calculations in which treatment technology and transport options were kept constant

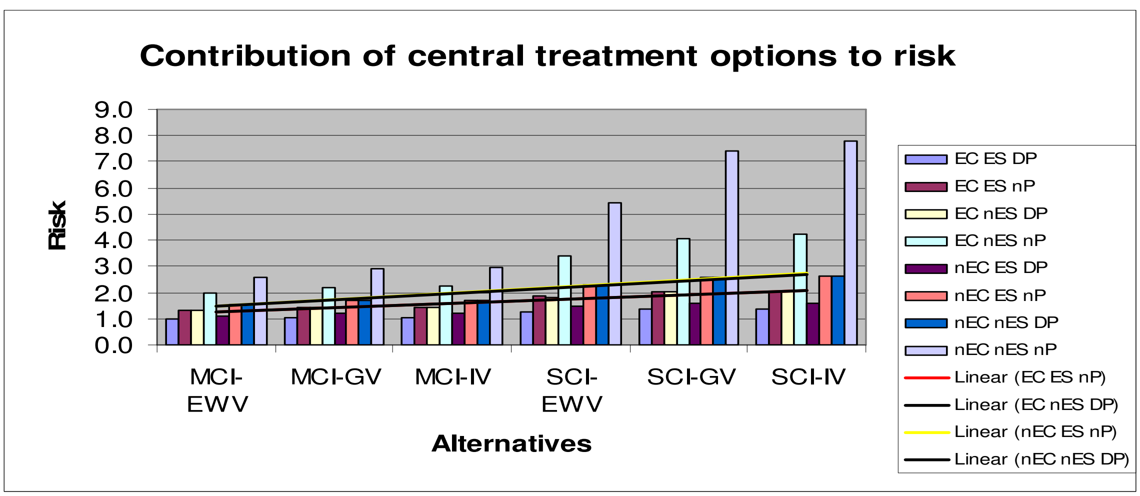


Figure 5.8(a): The contribution of central treatment options to risk

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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.

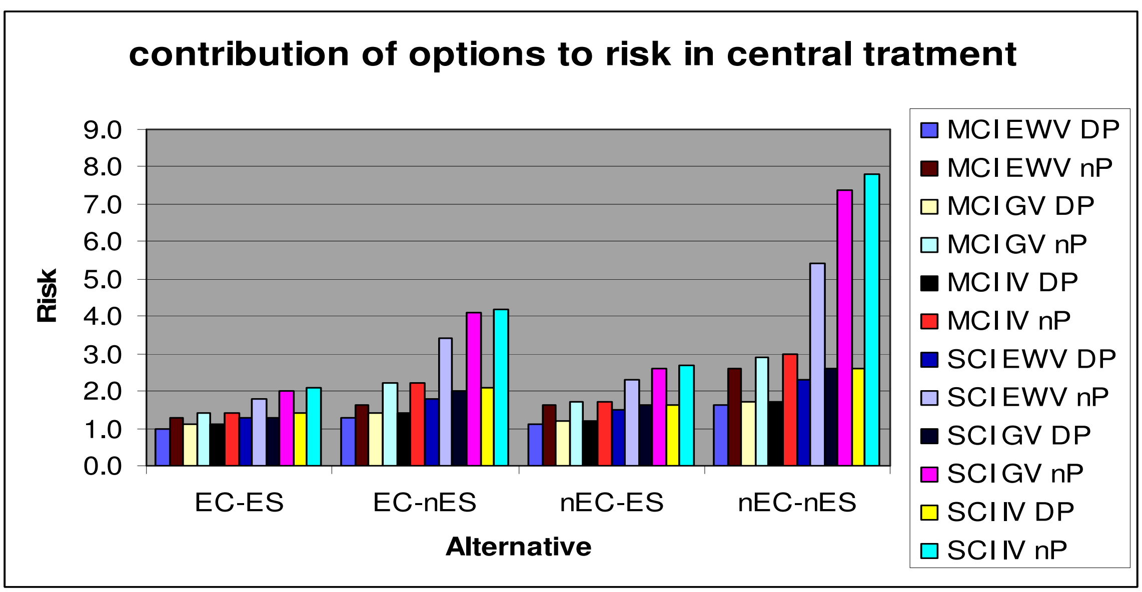
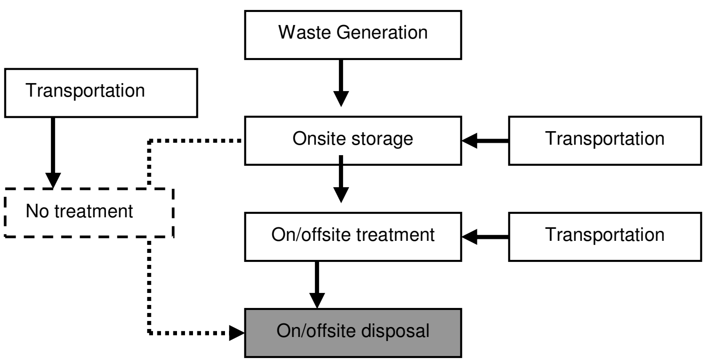


Figure 5.8(b): The contribution of central treatment options to risk

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.

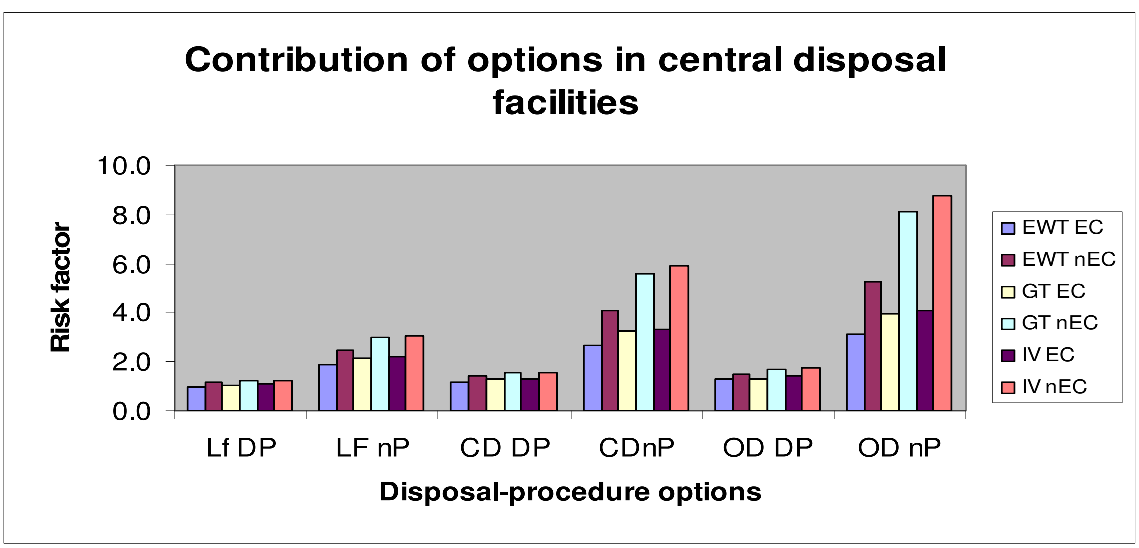


Figure 5.9: Contribution of off-site disposal options to risk

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.

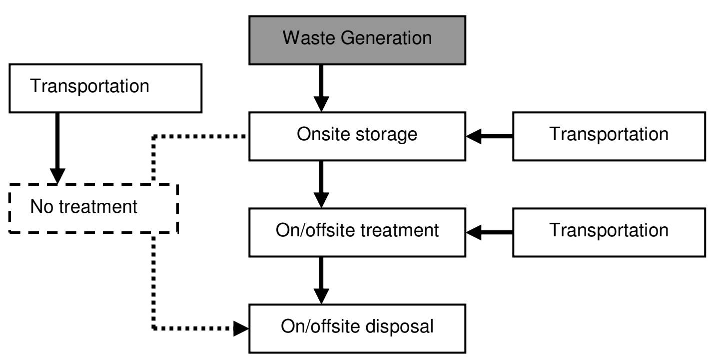
Table 5.3 below summarises the most important options that a decision-maker needs to consider per life cycle phase.

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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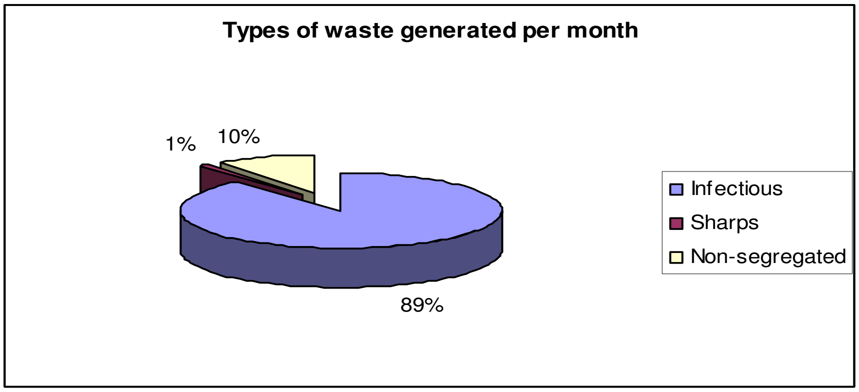


Figure 5.10: Waste generation rates

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.

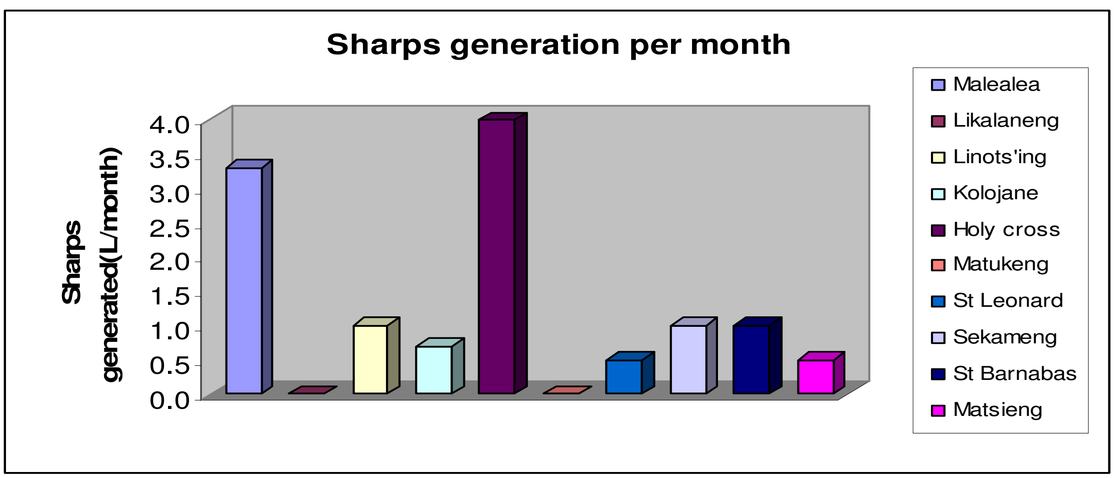


Figure 5.11: Generation of sharps per month (outpatients)

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.

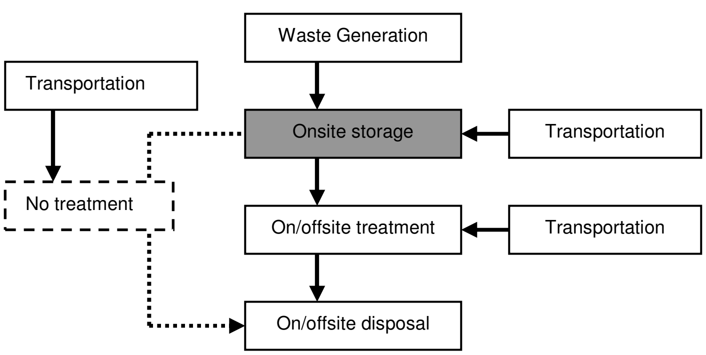
(d) Infrastructure

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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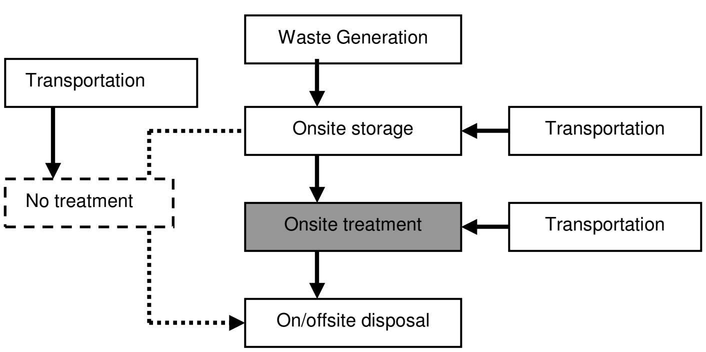
(b) Storage

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.

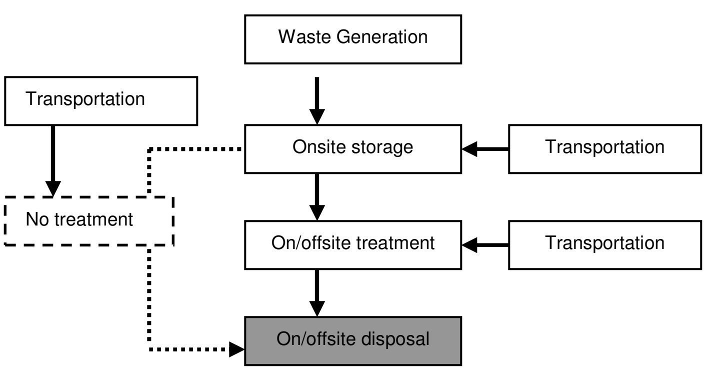
Due to the absence of a standard design and the absence of minimum requirements for incinerators, a variety of slightly different designs are used. The choice of the incinerator and its capacity depend on the funds available and on the design that contractors are able to propose to the clinic. The state 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.