REPORT

FEASIBILITY STUDY INTO THE POSSIBLE REGIONALISATION OF HEALTH CARE RISK WASTE TREATMENT / DISPOSAL FACILITIES IN GAUTENG

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REPORT ON FEASIBILITY STUDY INTO THE POSSIBLE REGIONALISATION OF HEALTH CARE RISK WASTE TREATMENT / DISPOSAL FACILITIES IN GAUTENG

NOVEMBER 2000

REPORT No. P99/024-03

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EXECUTIVE SUMMARY

Having identified a need for more co-ordinated and integrated Health Care Risk Waste (HCRW) management in Gauteng, the Gauteng Department of Agriculture, Conservation, Environment and Land Affairs (DACEL) prepared and issued Terms of Reference (ToR) to consultants during the latter half of 1999 for undertaking a Status Quo Study on HCRW management in Gauteng. This study was not only aimed at identifying and quantifying the various sources of HCRW in Gauteng, but it was also aimed at investigating and reporting on the available treatment/disposal facilities in the Province. The feasibility of regionalising HCRW treatment facilities were finally to be investigated in an attempt to come up with a broad strategy for the regionalisation of such facilities. Although siting scenario's for the proposed facilities were to be done, it was not required that specific sites be identified, as that was to form part of a follow-up project.

Having been successful in submitting a proposal to undertake the project, Kobus Otto & Associates Waste Management Consultants in Association with Environmental & Chemical Consultants, Executive Task Force, CSIR and Mabula Consulting Engineers were appointed. The appointment was to define and investigate the nature of HCRW and amount generated in Gauteng, status quo of HCRW treatment/disposal facilities, alternative HCRW treatment/disposal technologies, development of a customised module of the Environmental Information Management System (EIMS) in line with DACEL system to spatially represent the most prominent HCRW generators in Gauteng, as well as the existing HCRW treatment facilities. The final requirement was to undertake a waste transportation study that also considered the possible regionalisation of HCRW treatment facilities. The appointment was done according to the issued Terms of Reference (ToR).

The study started off with a literature review on HCRW practices implemented throughout the world, with particular emphasis on developing countries like South Africa, thus being able to identify shortcomings that may exist in present HCRW practices and to ensure that the recommendations made are in line with the relevant international standards.

With limited information available on potential generators of HCRW in Gauteng, the next step was to undertake an investigation that led to the identification of some 600 HCRW generators (community health centres, clinics and hospitals) that were subsequently classified as "major generators" and approximately 9,700 HCRW generators (medical doctors, veterinary surgeons, etc.) classified as "minor generators". To be able to make use of the survey data for extrapolation to facilities that were not surveyed, the potential generators were grouped into 5 different categories. Due to the limited impact that it was expected to have on the overall waste stream as well as the difficulty in obtaining such information, HCRW generated at private residences were not considered. Human corpses and animal carcasses were finally specifically excluded from the study.

Consultations with the personnel involved on various levels of HCRW management were then conducted during site visits to the Health Care Facilities. This was not only to obtain first-hand information on the conditions that exist at the generators, but also to do physical weighing of the HCRW stream at a selected number of facilities. Questionnaires, specially designed with the aid of research specialists to ensure that its appropriateness for the respective categories of HCRW sources, were used during the survey.

Resulting from the impact that the wide range of occupancy rates would have had on the HCRW generation rates, it was decided not to make use of a rate in kg/bed/day, but rather in kg/patient/day, which required that the bed occupancies be determined for the particular period over which the survey

was conducted. For facilities where patients were not staying overnight, the HCRW generation rate in kg/patient or alternatively in kg/facility, was used for further extrapolation of the data.

It was found from the survey that the mass of HCRW generated ranges between 0,06 and 0,48 kg/patient/day for private clinics and between 0,002 and 0,05 kg/patient/day for public clinics. For hospitals, the mass of HCRW generated varies between 0,5 and 4,04 kg/patient/day for private hospitals and 0,23 and 2,43 kg/patient/day for public hospitals. Using statistical procedures, the total HCRW mass generated in Gauteng is estimated (with 95% confidence) not to be greater than 1 175 tons per month. It was also found that the approximately 600 "major" generators contribute about 89% and the approximately 9 700 "minor" generators about 11% of the total HCRW stream generated in Gauteng.

Although analysis of the waste composition did not form part of this study, it became evident that poor segregation of Health Care Waste (HCW) results in general waste not requiring incineration being disposed of with HCRW, and in HCRW being disposed of as general waste, which creates a health and safety risk to waste disposal site workers as well as the public at large. This particularly applies where there is poor access control at the waste disposal facility. The presence of polyvinyl chloride (PVC) in the waste stream in turn results in the emission of toxic fumes at the incinerators.

General observations made on the status of HCRW management at Gauteng Health Care Facilities indicated that the HCRW storage, collection and transportation in most instances does not meet the required standards and there are only limited awareness and education programmes on management of HCRW. Personnel responsible for awareness and education of the risks associated with HCRW and responsible management procedures were not conversant about their roles.

The investigation on the HCRW treatment facilities in Gauteng, (these are all incinerators) revealed that of the 70 incinerators located at 58 Health Care Facilities, only 58 (83%) are operational and only 25 (37%) are registered with the regulatory authorities. Only one of the incinerators is equipped with a scrubber, which appears to be mostly out of operation. Ash from the incinerators is in most instances disposed of as part of the domestic waste stream or alternatively mixed with the boiler ash, before being disposed of at general waste disposal sites. Whilst incineration is currently the only HCRW treatment method used in Gauteng (and, we understand, throughout South Africa), alternative technologies such as chemical disinfection, autoclaving and microwave technology could offer cost effective and environmentally acceptable solutions if fully developed.

As part of the project, a HCRW Incinerator Information Management System (IIMS) module was developed to form part of the existing Environmental Management System used by DACEL. This included a customised user-friendly module of the Environmental Impact Management System (EIMS) for accessing and maintaining the incinerator data in the form of maps, graphs and reports. Spatial representation of data on both the sources of HCRW generation as well as the treatment/disposal facilities was updated on DACEL's EIMS within a Geographical Information System (GIS). Future developments of the IIMS may require the addition of further components, as the need for capturing additional information becomes necessary. The current system allows for upgrading and development as DACEL's needs develop.

The study found that the current practice of incinerating HCRW "on site" at provincial hospitals is comparatively uneconomic. The cost of "on-site" incineration of HCRW, plus the costs associated with the use of third-party removal/incineration of HCRW from provincial hospitals by contractors, is estimated to be approximately R810,000 per month. Application of the numerical model developed as part of this study suggests that this monthly cost could be reduced to approximately R570,000 if two new facilities are brought into operation: one at or near the Greater Johannesburg Metropolitan Council's ("GJMC") Marie Louis landfill site in Roodepoort, and one at or near the GJMC's proposed Northern Works landfill site, north of Dainfern. A fleet of purpose-built vehicles would be used to transport the HCRW from hospitals to these facilities.

When applied to the total estimated HCRW stream emanating from both provincial hospitals and clinics, the model indicates that the optimal (i.e. minimum cost) configuration of incineration facilities (with or without gas-scrubbers) comprises three new facilities: one at or near the Marie-Louise landfill site (600kg/hour), one at or near Tambo Memorial Hospital (new 300kg/hour unit replaces existing) and one at or near the Pretoria Academic Hospital (new 300kg/hour unit replaces existing). This scenario remains optimal when the possible addition of 800 new beds at Pretoria Academic Hospital is taken into account.

A scenario substituting a new facility at or near the Pretoria Metro's Hatherley landfill site instead of the upgraded Pretoria Academic Hospital facility suggested above, indicates that there would be a cost-penalty of approximately 10% over the optimal scenario; this scenario is, however, relatively sensitive to increased transportation costs.

Various other siting scenarios were investigated, and the results summarised for easy reference. *Inter alia*, these scenarios indicate that the use of only one or two new/upgraded facilities, or the use of four or more facilities, results in increased costs.]

Having reference to a number of the best (i.e. least-cost) siting scenarios as determined in this study, a thorough investigation should be undertaken at and in the vicinity of the proposed siting locations to confirm the availability and suitability of sites for possible new facilities. Detailed feasibility studies should further be undertaken for the proposed new facilities. Detailed feasibility studies should further be undertaken for the proposed new facilities, and for the HCRW transport system to be used. Based on the outcome of such detailed studies, the financial model developed for this study should be used to confirm that the proposed regionalisation strategy remains the optimal solution.

Based on the observations made during the study, it is recommended that a detailed analysis of HCW composition from hospitals and clinics be conducted to quantify the potential for recycling and savings that are likely to be achieved through improved HCW segregation. This should be accompanied by the development of standardised policy guidelines and awareness training material on responsible handling of HCW, including segregation and possible recycling of same HCW at source. This material is ultimately to be included as part of formal training of new staff members and regular refresher courses for existing staff members.

Alternative ways of reducing the use of PVC in Health Care Facilities should also be explored in order to reduce the possible generation of toxic fumes during the incineration thereof, together with a study on the appropriateness of using alternative treatment/disposal technologies to incineration.

All new incinerators commissioned in Gauteng should be permitted to operate on condition that they comply with the DEAT 2009 emission guidelines, which may require that scrubbers be fitted. The current incinerators should be appropriately upgraded or phased out by 2009. It is further recommended that the

DACEL EIMS be updated as new information on Health Care Facilities as well as HCRW generation and treatment facilities becomes available.

It is finally recommended that a regionalised approach be followed to the treatment/disposal of HCRW emanating from provincial hospitals and clinics in Gauteng. This recommendation is supported both by economic considerations, as well as by administrative considerations such as the ease of control/monitoring of the small number of facilities proposed, thus ensuring compliance with environmental regulations. The design-capacity of the regionalised facilities will, however, have to be carefully determined, taking into account factors such as the anticipated growth in the mass of HCRW generated, and whether the facilities should be sized also to cater for the HCRW generated by the private sector, particularly in view of the tighter regulatory environment envisaged in the future.

By making use of the proposed optimal facility scenario as a basis, a thorough investigation should be undertaken at and in the vicinity of the proposed siting locations to confirm the availability and suitability of sites for possible new facilities. Detailed feasibility studies should further be undertaken for the proposed new facilities, and for the HCRW transport system to be used. Based on the outcome of such detailed studies, the financial model developed for this study should be used to confirm that the proposed regionalisation strategy remains the optimal solution.

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1. INTRODUCTION

1.1 Background

Towards the end of 1999, the Gauteng Department of Agriculture, Conservation, Environment and Land Affairs (DACEL) issued Terms of Reference (ToR) for investigating the Feasibility of Regionalizing Health Care Risk Waste Treatment/Disposal for Provincial Hospitals in Gauteng.

During November 1999, Kobus Otto & Associates Waste Management Consultants, in association with Environmental & Chemical Consultants, Executive Task Force, CSIR and Mabula Consulting Engineers submitted a proposal (Report No. P99/024-01) in response to the DACEL's ToR. The proposal, which was subsequently approved, called for the confirmation or otherwise of the ToR. The revised ToR (Report No. P99/024-02) was submitted to DACEL.

1.2 Terms of Reference (ToR)

The revised ToR objectives for this project were to:

- Define health care waste (medical waste) and its components;
- Determine the current Health Care Risk Waste (HCRW) types and generation rates expressed in kg/bed and kg/patient;
- Explore different future scenarios on medical waste generation rates for Gauteng;
- Determine the number and location of Medical Waste Treatment Facilities, including their capacities, operational status, compliance to 1994 DEAT emissions guidelines as well as remaining lifespan;
- Capture both the sources of medical waste generation and existing HCRW Treatment Facilities on DACEL's Environmental Information Management System (EIMS), which is in the spatial representation form of a Geographic Information System (GIS);
- Determine the maintenance and operation costs of the existing HCRW treatment/disposal facilities based on current (2000 Emission Requirements) and future policy compliance (2009 Emission Requirements);
- Determine the feasibility of developing a regional HCRW treatment/disposal facility or facilities for Gauteng. This would be looked *at vis-à-vis* operating upgraded individual facilities;
- Investigate and recommend alternative siting scenario's for locating HCRW treatment/disposal facilities, considering both the environmental and the economic viability;
- Develop a broad HCRW (medical waste) collection and transportation strategy to meet the needs of various alternative sites for HCRW treatment/disposal facilities;

- Briefly evaluate opportunities for restricting the use of certain materials, such as PVC, that can lead to hazardous waste streams;
- Investigate and make recommendations on HCRW awareness; and
- Investigate potential need for HCRW movement across provincial borders.

The ToR also called for the presentation and production of a popularised and summarised version of the findings.

1.3 Approach and Methodology

1.3.1 Desktop study and consultations

The success of a study of this nature requires the co-operation of those who deal with HCRW in order for existing site conditions to be accurately recorded. A number of steps were taken to ensure maximum participation by parties involved in HCRW i.e.:

- Local and international literature was reviewed to identify the participants in HCRW, the current situation regarding generation and treatment facilities and the latest approaches in HCRW management;
- Site visits were made to do physical weighing of the HCRW stream generated at selected institutions, identify problems that may exist, collect the necessary statistical data and to acquaint the investigating team with prevailing conditions;
- The HCRW generation rates per patient were determined at the facilities where physical weighing was done to obtain the total Provincial HCRW generation rates by means of extrapolation;
- Consultations were held with various Provincial and National Departments as well as Private sector companies that deal with HCRW, in order to determine the most effective integrated approach;
- Different questionnaires were developed to be relevant to the various categories of HCRW generators, such that salient details required for the study were obtained from the respective HCRW generators.

1.3.2 Field surveys

Purpose of the survey

The aim of the survey was to:

- Obtain information concerning the HCRW generation rates by means of physical weighing that would ultimately determine the level of infrastructure required;
- Acquire the occupancy rates on the number of patients (past and present) that generate HCRW so as to be able to predict future trends and to be able to extrapolate the information to facilities that were not physically measured;
- Obtain first hand information regarding the standards for and conditions under which HCRW is managed;
- Determine the physical positions of the incinerators by means of a GPS device.

The information on the hospital occupancy rates was obtained by means of interviews together with completion of the relevant questionnaires. In other areas, questionnaires were sent to the respondents by means of a fax.

Survey methodology

The field survey *inter alia* involved the following activities:

- Collection and recording of statistical information related to the occupancy (past and present; and
- Collection and weighing (by using purpose made calibrated scales) of HRCW generation over an average period of five days from each HRCW generator. Where possible, the waste generation rates were recorded according to the source (ward or theatre in which it was generated). Where HCRW is not collected daily, surveys were limited to the day of collection. This information was later related to the occupancy rates for the period over which the HCRW was generated.
- Observations related to the way in which HCRW is managed at source, as well as the strategies followed with regards to the treatment/disposal thereof were made.

1.3.3 Limitation of the study

As it was not physically possible to measure HCRW masses at all potential sources, a “sampling” procedure had to be adopted. Although HCRW generation figures are internationally often expressed in kg/bed/day, a decision was taken rather to express the generation rates in terms of kg/patient/day, as the occupancy rate of some Health Care Institutions was way below their available capacities, whilst others exceeded full capacity.

With any “sampling” procedure there is the danger that the sampled values (in this case HCRW mass/patient/day or mass/patient treated in the case of clinics) give a misleading picture as to the values in the total population. This is particularly true when the sample size is small in relation to the population size. For example, if one wished to determine the average height of the pupils in a school having 1,000 pupils, but the researcher only had the time to measure a “sample” of say 50 pupils, it can be expected that the average height of the sample of 50 pupils would not be identical to the average height of ALL the pupils. In cases like this, one option is to resort to statistical techniques which, although it cannot predict the exact value for the average height of all the pupils, can predict with a given degree of confidence that this average will be between certain limits, for example: “the 90% confidence interval for the average height of the school pupils is 1.25 to 1.75 metres”. From a confidence interval like this, other deductions can be made, viz. there is only a 10% (100% - 90%) likelihood that the actual average is outside the range stated and, further, there is only a 5% likelihood (10% / 2) that the actual average is less than 1.25 (the lower limit) or that it is greater than 1.75 (the upper limit).

In the case at hand, DACEL is essentially concerned with the upper limit of HCRW generation in the province, i.e. it would like to be confident that the capacity of existing or planned future HCRW incineration/destruction facilities is/will be adequate to treat the HCRW stream generated.

To assist with the interpretation and extrapolation of the HCRW generation data, statisticians from the University of the Witwatersrand were employed. They recommended that the "upper 90% confidence limit" be used in the extrapolation of the HCRW generation figures, which means that there is a 95% certainty that the actual mass of HCRW generated in Gauteng will not exceed the mass estimated in this study. (The statistical calculations are described in Annexure 3.3 and elsewhere in this report.).

With the exception of certain public institutions showing a zero increase in HRCW waste generated from 1995 to 2000, the HRCW waste generators did not have the necessary waste generation data for previous years which renders it impossible to predict future HRCW trends based on historical statistics. Some of the factors likely to have an effect on the HCRW generation rates are:

- The population growth rate (as projected from historical trends) will result in an increase in the rate at which HCRW is generated;
- The increase in AIDS-related illnesses could on the one hand result in an increase in the HCRW generation rates as more people fall ill, whilst it could in the worst case result in a negative growth in the population which will ultimately result in a reduction in HCRW generation figures;
- Improved HCRW awareness could result in better segregation of waste with a net reduction in the overall HCRW generation rates;
- A tendency towards the use of more disposable materials could result in an increase in the HCRW generation rates;
- Improved HCRW treatment standards may lead to higher treatment costs, which could result in a more dedicated effort being made by the generators to reduce their HCRW streams.

Due to the many variables that could have an effect in either direction on the projected growth of HCRW generation, it was not possible to predict a growth rate with any degree of certainty. As a sensitivity analysis proved that the outcome of the investigation was not significantly affected by the HCRW growth rate, it was finally decided to assume an average growth rate of 0% for the purpose of this investigation.

Other limitations included a delayed start to the project as a result of insufficient capacity building amongst the various stakeholders, a lack of information regarding potential HCRW generators which made it difficult to determine the required sample size as well as limited time available for the study when considering that the consultants had to do the physical weighing of HCRW at the generators.

1.4 Purpose and Scope of the Report

This report *inter alia* covers the following:

- The methodology adopted in conducting the study, as well as the limitations encountered;
- The status with regards to the number, types and locations of HCRW sources in Gauteng. The rates and mass of HCRW generated at the full spectrum of generators is covered;

- The status quo on the HCRW treatment facilities in terms of its location, ownership, types, sizes, capacity, condition and current operating costs;
- A visual perspective of the major HCRW generators as well as the treatment facilities by means of a customised module of the Environmental Information Management Systems (EIMS) for accessing and maintaining HCRW generators and treatment/disposal facility data captured on DACEL's EIMS;
- Recommendations on alternative siting scenarios for HCRW treatment facilities in Gauteng; and
- Conclusions reached with regard to the question of possible regionalisation of HCRW treatment/disposal facilities in Gauteng.

2. NATIONAL AND INTERNATIONAL REVIEW OF HEALTH CARE RISK WASTE MANAGEMENT

2.1 Background

The term 'Medical Waste' or Health Care Risk Waste (HCRW) has various interpretations. In clinics and hospitals for example, it would be associated with sharps, used bandages etc. while pharmaceutical firms might refer it to expired or spoiled medicines in their retail or manufacturing process. The purpose of this chapter is to define and analyse the various components of Medical Waste or Health Care Risk Waste.

Although this report will make use of the internationally accepted terminology, it is important that a link be created to the existing standards and requirements laid down in South Africa, i.e. the Minimum Requirements for the Classification, Handling and Disposal of Hazardous Waste [1] and the National Waste Management Strategy. For this reason the definition of hazardous waste in accordance with the Minimum Requirements will be discussed to define where HCRW will fit into this.

This chapter therefore reviews the current practices of Medical or Health Care Risk Waste Management in South Africa, also covering the nature and definition of Medical or Health Care Risk Waste. The review is primarily based on literature studies and consultations with various role-players in the industry.

2.2 Nature and Definitions of Medical or Health Care Risk Waste

Medical or Health Care Waste can be separated into a number of categories that identify the major hazard characteristic or risk that they pose to human health and the environment. These categories are divided as follows: -

- Infectious;
- Chemical (includes pharmaceutical waste);
- Radioactive; and,
- General waste.

Each of these can be divided into subcategories in a number of ways. Often a specific hazard may be specified, e.g. sharps, that includes any waste that may puncture the skin and thus introduce infection, or alternatively the source or origin of the waste may be specified, e.g. pharmaceutical waste.

In South Africa, various attempts at legislating hazardous wastes have given rise to somewhat different approaches and definitions. In terms of the Minimum Requirements for the Classification, Handling and Disposal of Hazardous Waste [1] published by the Department of Water Affairs and Forestry, infectious waste, chemical waste and radioactive waste are all defined as *Hazardous Waste***.** The United Nations and others have termed the hazardous wastes coming from health care facilities "*Health Care Risk Waste (HCRW)*" and GDACEL opted to use the latter term throughout this project.

2.2.1 The South African approach to the classification of Health Care Risk Waste (HCRW)

In South Africa, infectious waste is considered a sub-category of hazardous waste. The "Minimum Requirements for the Classification, Handling and Disposal of Hazardous Waste" (DWAF, 2nd edition, 1998) uses as a primary classification scheme the International Maritime Dangerous Goods (IMDG) Code, which has been published as SABS Code 0228**.** The code divides hazardous materials, in this case hazardous wastes, into 9 categories based on their hazardous characteristics, and even though HCRW may not fall under all of these, it is presented for the sake of more clarity.

- Class 1 : Explosives;
- Class 2 : Compressed Gases;
- Class 3 : Flammable Liquids;
- Class 4 : Flammable Solids;
- Class 5 : Oxidising Substances and Organic Peroxides;
- Class 6 : Toxic and Infectious Wastes, subdivided into
  - Class 6.1 : Toxic (poisonous) Wastes;
  - Class 6.2 : Infectious Wastes;
- Class 7 : Radioactive Wastes;
- Class 8 : Corrosive Wastes; and;
- Class 9 : Miscellaneous Dangerous Wastes.

Note that infectious waste is a subcategory of Class 6. Other wastes produced at the Health Care Facilities include Class 6, toxic materials such as pharmaceuticals, drugs and cytotoxic substances; flammable liquids such as ether, alcohol and many formulated products such as cough mixtures; radioactive substances, which are Class 7; and compressed gases, which are Class 2. Radioactive wastes and infectious wastes are generally managed separately from the other categories, which are all classified as chemical hazardous waste, whether they arise from a Health Care Facility or the chemical and petroleum industry.

2.2.2 Definition of hazardous waste

In order to compare the definition of HCRW with that of hazardous waste, the definition of hazardous waste, as outlined in the "Minimum Requirements for the Classification, Handling and Disposal of Hazardous Waste" (DWAF, 2nd edition, 1998) is:

'*Waste that may, by circumstances of use, quantity, concentration or inherent physical, chemical or infectious characteristics, cause ill-health or increase mortality in humans, fauna and flora, or adversely affect the environment when improperly treated, stored, transported or disposed of.'*

Note that the health care *infectious waste* stream is considered in this definition as a hazardous waste.

2.2.3 Definition of infectious waste

There are numerous definitions used for infectious waste and after considerable deliberation, a modified version of the definition used in the Minimum Requirements is recommended, which is subject to consultation before it will be finally accepted as the recognised definition

'Infectious waste is that waste that contains or is suspected to contain pathogens, bacteria, viruses, parasites or fungi in sufficient concentration or quantity to cause disease in susceptible hosts. It includes any waste that is generated during diagnosis, treatment or immunisation of humans or animals; in research pertaining to this; in the manufacturing or testing of biological agents – including blood, blood products and contaminated blood products, cultures, pathological wastes, sharps, human and animal anatomical wastes and isolation wastes.'

The definition is conservative and utilises the Precautionary Principal. Although much of the waste would not be hazardous, the risks posed by its potentially infectious nature are sufficient that it must be considered infectious unless proven otherwise. In South Africa, the waste is classified in terms of SABS Code 0228, "The Identification of Dangerous Substances and Goods" as Class 6.2: Infectious Substances.

Within the definition of infectious waste are two subcategories that are sometimes referred as follows: -

Anatomical (Pathological) Waste is waste that consists of tissues, organs, body parts, foetuses and animal carcasses (excluding blood and body fluids, teeth, hair, etc.)

The sub-category, anatomical waste, is useful since it is usually managed in different ways to other infectious wastes. In terms of the Human Tissue Act, human tissue must be incinerated and because of its generally offensive nature, technologies such as autoclaving and microwaving are not generally appropriate. In South Africa, religious customs, for example in the Muslim community, may require the burial of certain items of anatomical waste and this must be taken into account in the development of the procedures for anatomical waste management.

Sharps are items that could cause cuts and puncture wounds and includes needles, hypodermic needles, scalpels and other blades.
Sharps and in particular needles that give rise to "needle stick" injuries are a major health hazard in Health Care Facilities.

Infectious waste, such as old bandages, plasters, sanitary towels and babies nappies are often disposed with the general waste. In the United Kingdom this infectious or potentially infectious waste collected from households with the general waste stream is not considered a major problem, because it is generated from a "generally healthy population". The same approach is generally accepted in South Africa, since like other hazardous waste in general waste, it is usually catered for when the landfill sites are constructed and operated. The same approach cannot be followed in all hospitals.

However, when the potentially infectious waste is collected in increased volumes, such as *sanitary waste* from ladies toilets, in public areas such as large buildings, shopping malls and airports, then the risk becomes slightly greater. In South Africa, there are a number of companies rendering services that provide storage bins in toilets and a regular collection service. Often these wastes are disinfected with a "proprietary disinfectant", the bins cleaned and the waste disposed to landfill. There has been no real control over this practice, although the Department of Water Affairs and Forestry have requested each operator to assess their monitoring, treatment and disposal procedures.

2.2.4 Chemical Waste

The definition of chemical hazardous waste is given above under hazardous waste, if one excludes the infectious characteristic. Chemical hazardous waste includes any waste that has one or more of the following four characteristics:

- Corrosivity, pH <6 and pH >12
- Reactivity, (explosive, reacts with water, air or other wastes)
- Flammability, Flash Point $<61^{o}C$
- Toxicity (poisonous)

Toxicity is defined in terms of the following parameters:

- Acute toxicity to mammals (LD_{50},);
- Ecotoxicity (LC_{50}, 96hr, fish);
- Chronic toxicity;
- Carcinogenicity,
- Mutagenicity;
- Teratogenicity;
- Biodegradability;
- Persistency;
- Bioaccumulation;
- Concentration; and;
- Assimilation capacity of the environment.

Using these parameters the Minimum Requirements, classifies chemical waste into five hazard groups i.e. (HG1, HG2, HG3, HG4, Non-toxic) as follows: -

Extreme Hazard (Group 1) is waste containing significant concentrations of extremely hazardous waste, including certain carcinogens and teratogens and infectious wastes.

High Hazard (Group 2) is waste with highly toxic constituents.

Moderate Hazard (Group 3) is waste, which is moderately toxic or which contains constituents that are potentially moderately harmful to human health or to the environment.

Low Hazard (Group 4) is waste that contains potentially harmful constituents in concentrations that would represent only a limited threat to human health or to the environment.

Non-toxic - Hazard Rating Lower than Group 4 if the hazard rating falls below hazard rating 1 to 4, the waste can be considered as non-toxic (N/T) and be disposed of as a de-listed hazardous waste in a permitted general waste landfill.

Within the definition of chemical waste are a number of subcategories that are sometimes used as follows: -

Genotoxic waste has mutagenic, teratogenic or carcinogenic properties.

Note that genotoxic wastes, which include *cytotoxic (or antineoplastic)* drugs, are simply a sub-class of chemical waste and generally fall into the extreme hazard, HG1, and high hazard, HG2, groups.

Pharmaceutical waste includes expired, unused, spilt and contaminated pharmaceutical products, drugs, vaccines and sera that are no longer needed.

This category, which is simply an indication of the source of the waste, is not very useful since it implies to many people that the wastes are somehow different to chemical and other wastes. Whilst live vaccines and possibly sera must be managed as infectious waste, most pharmaceuticals contain one or more active chemical ingredients that are often toxic plus many other chemicals added to act as a carrier for the drug, to add flavour, etc. Almost all pharmaceuticals must be treated as a hazardous chemical waste. For example, the redundant or waste pharmaceuticals can include the following: -

- Active ingredients, many of which are highly toxic. For example, Warfarin is used to treat heart conditions but it is also a rat poison. In addition, a study on a list of 90 active ingredients used by a local pharmaceutical manufacturing company, found more than 70% to contain organochlorine or other organohalogens, hydrogen chloride and/or sulphur. All of these would generate acid gases on incineration.
- Flammable solvents, including chlorinated solvents such as chloroform, which is often a constituent of cough mixtures.
- Fillers, flavouring agents and preservatives, many of which could produce hazardous emissions in an incinerator that does not have a scrubber. An example is the use of mercury compounds as a preservative in some eye drops - although the concentration is very small.
- Packaging that can include PVC that will definitely give off considerable quantities of acid gases and can contain lead compounds. Packaging can also be labelled with dyes containing hazardous heavy metals such as Cd, although many packaging manufacturers have become aware of the problems with the combustion of these dyes and have stopped using them

Compressed gases include gas cylinders, gas cartridges and aerosols.

In general, gas cylinders are not a problem for the health facility as they are recovered by the suppliers, both because they are valuable and in terms of the duty of care. Compressed gases are SABS Code 0228, Class 2 wastes. Aerosols should be discarded only when empty and never included in the infectious waste stream, since they explode in an incinerator causing damage to the refractory lining and the rapid expansion of the gas gives a transient increase in the emission of particulates and other pollutants.

Heavy Metal Wastes includes mercury from broken thermometers, blood pressure gauges and used batteries.

Mercury and its compounds are an extreme hazard, HG1 and must be managed as a chemical hazardous waste.

2.2.5 Radioactive Waste from Health Care Facilities

Radioactive waste, which includes solid, liquid and gaseous wastes, contaminated with radioactive nuclides is generated in health care facilities in two forms, *unsealed* or open sources and *sealed* sources. Sealed sources are usually contained in equipment or as needles or seeds that may be re-used after sterilisation for other patients. The disposal procedures for sealed sources differ from those for unsealed sources. Sealed sources are usually disposed at the Atomic Energy Corporation's landfill site at Pelindaba or even re-exported to their country of origin.

Radioactive material is defined as any substance, which consists of or contains any radioactive nuclide whether natural or artificial and whose specific activity exceeds 74Bq/g (0.002μCi/g) of chemical elements and which has a total activity greater than 3.7kBq (0.1μCi).

The unsealed sources of radioactive material used in health care facilities usually results in low-level radioactive wastes (<1MBq), but waste in sealed sources may be of fairly high activity. In general, the low-level waste can be disposed with the normal infectious waste stream provided the appropriate controls are in place. However, the treatment of sealed or high level radioactive waste with the infectious waste stream must be avoided particularly when it is to be incinerated, since the ash and even the incinerator can end up being contaminated with unacceptable levels of radioactivity.

The definition of low-level waste is based on the concept of "Annual Limit on Intake" (ALI) and there are different ALI values published for ingestion and inhalation. The ALI_{min} is the lesser of these two values for each radionuclide and a table of values has been published (Department of Health, Cape Town). For both solid and liquid waste the total activity supplied to the disposing facility, i.e. sewer, incinerator or even landfill cannot exceed 10 ALI_{min} per month for each laboratory or corresponding entity and each release to the sewer or package containing solid waste must not exceed $1ALI_{min.}$

2.3 Composition of the Health Care Infectious Waste

The composition of South African Health Care Risk Waste that is treated at the incinerators is not known. Poor separation at source means that considerable quantities of general waste end up in the HCRW stream and is thus incinerated at high cost. In the USA, the so-called "red bag" waste that is infectious has considerably different composition to the general waste produced at hospitals and the normal municipal waste stream as presented in *Table 2.1* below.

Table 2.1: *Composition of infectious waste and hospital general waste according to Brown (1989)*, HL Brown, Thomas Jefferson University Hospital Waste Characterisation Study, Drexel University, 1989*

Material	**Infectious Waste, %**	**General Waste, %**
Paper	31.0	36.0
Cardboard	0.0	3.0
Plastic	29.0	20.0
Rubber	12.0	1.4
Textiles	5.0	2.1
Food	1.0	11.7
Yard waste	0.0	2.0
Glass	3.2	4.8
Metals	1.1	7.2
Fluids	17.7	9.9
Misc. Organics	0.0	1.9
TOTAL	**100**	**100**

Clearly, the major differences in the two waste streams reported in ***Table 2.1***, are the higher amounts of plastics, rubber and fluids and the very low amounts of food waste in the infectious waste stream compared to the hospital general waste. The higher amounts of plastic and rubber indicate that the waste has a higher calorific value compared to the general waste stream. In many countries, the amount of plastic in the medical waste and the use of disposable items have increased over the last 10 years and it is believed that South Africa is no exception, although there is no good data to support this. According to one South African medical supplier they have reported an increase in the sale of disposables including theatre gowns and bed sheets in South Africa in the last few years, with up to 10% per annum in the private hospitals, but only 3% per annum in the Provincial Hospitals.

As many as six different plastics are used in the waste stream i.e. polypropylene, polyvinyl chloride, polystyrene, polyethylene, polycarbonate and various mixed plastics. Only one, polyvinyl chloride (PVC), contains organochlorine and the amount found in an incinerator feed is closely related to the production of hydrogen chloride and may influence the emission of the extremely toxic chlorinated dioxins and furans. The major items that contain PVC are vinyl gloves, intravenous administration sets, syringes and needles. The amount of PVC items used will clearly depend on the type of hospital but figures of the order of 60g per bed per day have been published (A E S Green, ed. "Medical Waste Incineration and Pollution Prevention", Van Nostrand Reinhold, NY 1992).

The potential impact of the combustion of pure PVC, which is 56.7% by weight of chlorine, becomes clear when it is noted that 1kg would yield 583g of HCl or equivalent to the amount of acid in ~1.7 litres of pool acid. Most PVC items contain plasticisers and other ingredients and therefore the amount of chlorine is significantly lower; for example flexible items have a high plasticiser content and consist of ~36% PVC, whereas rigid items contain much less plasticiser, 54%-64%. In addition, some of the HCl reacts with alkalis in the waste stream and therefore does not necessarily get emitted through the stack. The major use for PVC is in the construction of blood bags because of the low cost of the material, its good mechanical behaviour and acceptable biocompatibility. There are substitute materials available for both the flexible and rigid PVC items used in hospitals (A E S Green, ed. "Medical Waste Incineration and Pollution Prevention", Van Nostrand Reinhold, NY 1992) but they are currently not generally available and are presumably more expensive. However, the presence of PVC does pose a significant environmental burden, if scrubbers are not fitted to the incinerators, which is the norm in South Africa. Scrubbers add significant capital and operational costs to incinerators and depending on the size of the incinerator, i.e. the economies of scale that can be achieved, the cost for incineration can increase substantially. The "incineration cost models" developed for this study, and described in paragraphs 6.3.1 and 6.4.2 below, suggest that the increase is only approximately R0.29 (50%) in the case of large (900kg/hr plus) new facilities; however, for existing (mostly small) facilities like Tambo Memorial and Pretoria Academic Hospital, the increase ranges from R0.54 to R0.61/kg.

It must be noted that location of incinerators away from residential and sensitive areas can greatly reduce the risk of impacting on health and safety but the acid gases are still released. Alternatives to the use of acid gas scrubbers, which can probably considered to be an "end-of-pipe" solution, include banning the use of PVC, except where no alternatives are available, and the use of alternative technologies for the sterilisation of the waste such as autoclaving or microwaving. Proper separation at source should also reduce the amount of PVC entering the waste stream.

2.4 Treatment Technologies for Infectious Waste

2.4.1 Minimum requirements

According to the "Minimum Requirements for the Classification, Handling and Disposal of Hazardous Waste", *sterilisation* is a minimum requirement before disposal of any residue in a permitted H landfill [1]. The Department of Water Affairs and Forestry have interpreted this, as requiring incineration of infectious waste before disposal of the ash to a hazardous waste landfill. The reason for this is that the infectious waste disposed, such as sharps, can be reused, even if sterile. As many sites still have pickers, disposal at these sites would be unacceptable. Furthermore, it is difficult to monitor the sterility of infectious waste arriving at a landfill site, if it remains in its original containers. It is well known that infectious waste is finding its way into the general waste stream in considerable quantities – at best, this results in disposal at permitted landfills, but frequently infectious waste ends up in informal landfills or dumped in the veld.

The definitions of sterilisation and disinfection given below are based on those published by the Centre for Disease Control in Atlanta, Georgia (Pruss, 1999): -

Sterilisation is a process that reduces the number of microorganisms by a factor of one million (10^6 or more than 99.9999% are killed).

High-level disinfection is when all microorganisms, with the exception of small numbers of bacterial spores, are killed.

Intermediate Level Disinfection is where Myocardium tuberculosis, most viruses and fungi are killed, but not necessarily bacterial spores.

Low Level Disinfection is where most bacteria, some viruses and some fungi are killed, but the complete absence of resistant microorganisms such as tubercle bacilli or bacterial spores cannot be relied on.

Note that although sterilisation implies the complete absence of any microorganisms, the definition allows the presence of small numbers of microorganisms. For disposal purposes, sterilisation is an ideal that should be achieved, if possible. However, there may be circumstances (like in emergency situations where due to unforeseen circumstances insufficient incinerator capacity is available or where the transport distance from remote rural areas make it impossible to have the HCRW incinerated) where disinfection or possibly even no treatment could be acceptable, before disposal, is done. This statement can be motivated as follows:

Even though in South Africa, incineration is still the method of choice for infectious waste, there are a number of new technologies that are available that compete with incineration and can be accepted provided they meet certain objectives specifically focussed at the South African environment and conditions. The final choice depends on many factors, but must as a minimum meet certain environmental, health and safety requirements. Issues that must be considered are:

- The sterilisation or disinfection efficiency;
- The waste should not be accessible for reuse;
- The potential impact of poor segregation of wastes, e.g. impact of chemical wastes, aerosols, etc;
- The ability to meet the requirements of the Occupational Health and Safety Act;
- The emergency procedures required, e.g. after a needle stick injury;
- Regulatory requirements, including an Environmental Impact Assessment with public scoping;
- Any gaseous emissions including fugitive emissions;
- Disposal of water, e.g. to sewer;
- The quantity of waste for treatment and the capacity of the system;
- The volume of waste and mass reduction;
- The residues after treatment – classification and disposal procedures;
- Infrastructure and operation and maintenance requirements;
- Training requirements;
- Available space;
- Location;
- Capital and operating costs – the technology should be cost effective; and;
- Public acceptability.

It is proposed that:

"Any technology appropriate for South African conditions can be used, provided the operator/owner can demonstrate that it can meet all health, safety and environmental requirements including passing a full environmental impact assessment and public scoping study."

Possible acceptable alternative technologies that can be used to treat all or part of the infectious waste stream include incineration, chemical disinfection, autoclaving and microwave technology and these have been considered in some detail in a previous report (GDACEL, "Background Study on Medical Waste Management", by Infotox, November 1998) and only a limited discussion is included below**.**

2.4.2 Alternative technologies to incineration

A number of alternative technologies are being investigated in South Africa – these include:

- Chemical Disinfection
- Autoclaving
- Microwaving
- Plasma Arc Destruction and
- Thermal Depolymerisation Technology

In Phase 2 of this GDACEL study, the plans include an evaluation of the treatment and disposal options available and their advantages and disadvantages. These must be considered in terms of both National and Provincial priorities.