WASTE DISPOSAL OR DISCHARGE –

A HARMONISED REGULATORY FRAMEWORK TOWARDS SUSTAINABLE USE

BY

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OPGEDRA AAN MY OUERS, AWIE EN AMARIE BOSMAN, VIR HULLE LIEFDE EN DIE VOORBEELD WAT HULLE DAAGLIKS AAN MY STEL

Die aarde en alles wat daarop is, die wêreld en die wat daar woon, alles behoort aan die Here... **Psalm 24:1**

Die Here God het die mens in die tuin laat woon om dit te bewerk en op te pas. **Genesis 2:15**

As ek U hemel aanskou, die werk van U vingers, die maan en die sterre waaraan U 'n plek gegee het, wat is die mens dan dat U aan hom dink, die mensekind dat U na hom omsien?...
U laat hom heers oor die werk van U hande... **Psalm 8:4-7**

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Soli Deo Gloria

Outeursnota: Aangesien die meerderheid rolspelers in die veld van omgewingsbestuur Engelssprekend is, moes hierdie studie in Engels gedoen word sodat dit vir die betrokke gehoor toegangklik kan wees.

SUMMARY

The discharge of waste into a water resource and its disposal on land can easily cause pollution, especially of the water resource. However, it has long been accepted that these activities also form an integral part of a holistic waste management strategy aimed at achieving sustainability. The South African Constitution ensures a basic right to an environment that is not harmful to human health and wellbeing, and states that pollution must be prevented, the environment must be protected, and sustainable use of resources must be promoted, through "*reasonable legislative and other measures*". The other measures that are currently used by the Department of Water Affairs and Forestry to determine whether a waste disposal or discharge action is allowable, are contained in the documents "Procedures to Assess Effluent Discharge Impacts" and "Minimum Requirements for the Handling, Classification, and Disposal of Hazardous Waste". These measures are evaluated to determine whether they are reasonable and effective in distinguishing between sustainable use and pollution in terms of newly promulgated legislation aimed at managing the environment and the water resource.

The criteria used for this evaluation are based on the principles of sustainability, the components of risk analysis, and the scientific concepts and principles of waste discharge and disposal management. Based on this evaluation, the shortcomings of current mechanisms are highlighted, and their advantages are incorporated into a proposed integrated regulatory framework for an assessment and decision-making approach based on risk harmonisation, which has various advantageous applications, including:

- The identification of cleaner production alternatives;
- The identification of an appropriate medium of disposal or discharge (water or land);
- The selection of the Best Practical Environmental Option (BPEO) for treatment, disposal or discharge methods;
- The licensing of sustainable waste disposal or discharge actions;
- The setting of charges for waste discharge activities;
- The prioritisation of regulatory intervention; and
- The rehabilitation of contaminated areas.

The findings of this investigation comprise the first step taken in South Africa towards the harmonisation of assessment and decision-making approaches, which could have important implications for integrated waste and environmental management in the future.

Keywords: Sustainable use, regulation, water resource, pollution, risk assessment, waste, effluent, waste classification, risk management.

OPSOMMING

Die wegdoening van afvalprodukte op land, of die stort van uitvloeisel in 'n waterbron, lei maklik tot besoedeling, veral van die wateromgewing as hulpbron. Dit word egter ook al lank aanvaar dat hierdie aktiwiteite 'n integrale deel vorm van 'n holistiese afvalbestuursstrategie wat gemik is op die bereiking van volhoubaarheid. Die Suid Afrikaanse Konstitusie verseker 'n basiese reg tot 'n omgewing wat nie skadelik is vir menslike gesondheid of welstand nie, en vereis dat besoedeling voorkom moet word, die omgewing beskerm moet word, en volhoubare gebruik van hulpbronne aangemoedig moet word deur "*redelike wetlike en ander maatreels*" in plek te stel. Die "ander maatreels" wat die Departement van Waterwese en Bosbou tans gebruik om besluite te neem oor die toelaatbaarheid van afvalwegdoenings- en stortingsaksies word beskryf in die dokumente "Procedures to Assess Effluent Discharge Impacts", en "Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste". Hiérdie maatreels word geëvalueer ten einde te bepaal of dit redelik is, en effektief onderskei tussen volhoubare gebruik en besoedeling in terme van nuwe wetgewing wat daarop gemik is om die omgewing en die waterbron te bestuur.

Die kriteria vir hierdie evaluasie word gebaseer op die beginsels van volhoubaarheid, die komponente van risiko-analise, en die wetenskaplike konsepte en beginsels van afvalwegdoening- en uitvloeiselstortingbestuur. Gebasseer op hierdie evaluasie word die tekortkominge van die huidige benaderings uitgelig, en die voordele van elk word geïnkorporeer in 'n voorgestelde geharmoniseerde reguleringsraamwerk vir evaluering en besluitneming met potensiële toepassing vir:

- Die identifisering van skoner produksie alternatiewe;
- Die identifisering van die mees geskikte medium van wegdoening (water of land);
- Keuses vir die Beste Praktiese Omgewingsopsie vir die metode van behandeling en wegdoening;
- Die uitreiking van lisensies aan aksies wat volhoubaar is;
- Die bepaling van afvalwegdoeningsonkostes;
- Die bepaling van prioriteite vir intervensie deur die owerheid; en
- Die rehabilitasie van gekontamineerde areas.

Die bevindinge van hierdie ondersoek is die eerste stap in die rigting van die harmonisering van risikobepalingsbenaderinge in Suid-Afrika, en kan belangrike implikasies hê vir geïntegreerde afval- en omgewingsbestuur in die toekoms.

Sleutelterme: Volhoubare gebruik, regulering, waterbron, besoedeling, risikobepaling, afval, uitvloeisel, afvalklassifikasie, risikobestuur.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

The environmental deterioration of the earth, especially during the last century of the second millennium, has two main causes. The exponential increase in the world's population, the growing sophistication of its needs and activities for the maintenance of present-day lifestyles, and the process of industrialisation, have not only resulted in a vastly increased pressure on and depletion of the earth's essential natural resources, they have also caused the increased generation of enormous quantities of waste (Fuggle and Rabie, 1994:1; Barnard, 1997:225). The production of waste, an unavoidable and unwanted by-product of all man's activities, is characteristic of mankind, and inevitable in an industrial society (Asante-Duah, 1993:1). The more advanced the level of civilisation, the greater the production of waste, in liquid as well as in solid form (Fourie, 1994:199). Furthermore, indications from available data (Law, 1996:101) show that the amount and hazardous nature of waste generated is in almost direct relation to the growth of the economy.

South Africa is regarded as a developing country. Most of its larger industries are based on first world technology, and therefore produces first world waste, which normally contains a fairly large proportion of substances which potentially pose a risk of harm to humans and the environment. The demand on South Africa's resources can however be regarded as both first and third world, and a large number of its citizens utilise these resources directly (e.g. by obtaining drinking water directly from boreholes and streams). The management of waste, and especially its disposal, is a growing problem (Parsons & Jolly, 1994:1), since it may contain substances that, if not effectively controlled, can be harmful to humans and the environment (Blowers, 1994:72). This means that the protection required in order to maintain the integrity of these resources must be more stringent than in developed countries.

The climate of much of the country is semi-arid, and increasing population growth and urbanisation are leading to an increased demand on water resources, which causes the country to have to face serious water shortages (Department of Water Affairs (DWA), 1986:2.8). Owing to sedimentation in dams and the limited number of suitable dam sites, the water supply from surface water sources alone will not be adequate to address this demand into the next century and beyond. Although ground water accounts for only about 13% of the total national water supply, some 65% of the area of the country already relies on this component of the water resource to some extent. The predicted inability of the surface water component to meet future demands and the growing cost of developing these resources, suggest that the integrity of ground water resources must be protected, since this component will ultimately have to be utilised to meet these demands and requirements (DWA, 1986:3.19).

It has been shown throughout the world that the disposal of waste on land is a major contributor to the degradation of aquifers (Parsons & Jolly, 1994:1), and the discharge of water containing waste (effluents) into surface water resources has lead to the deterioration of these resources. It is therefore of the utmost importance to prevent this type of disposal or discharge and where prevention is not achievable, to ensure that such disposal or discharge is conducted in a manner that will not be detrimental to ground and surface water resources.

South Africa's water resource management policy does not aim to prevent the disposal or discharge of waste into the environment at all costs. This would not allow the country to achieve much-needed social and economic growth. What is needed is to find the right balance between using a water resource for the disposal or discharge of waste, and protecting a water resource against the potential harmful impact of such disposal. The National Water Act 36 of 1998 (NWA) makes provision for resource-directed measures as well as source-directed controls in order to achieve this balance. This implies that there must be a system in place that will show whether the disposal or discharge of waste will be detrimental to, or whether it will be a sustainable use of, the water resource. Such a system must take cognisance of the characteristics of the waste itself and the potential risks posed by the waste to people and to the environment over both the short and the long term, as well as the ability of the receiving environment to assimilate such risks, in order to determine which wastes must be avoided or treated, and which can be safely disposed of or discharged.

1.2 PROBLEM FORMULATION

In South Africa, there has traditionally been a differentiation between the disposal of waste on land in a waste disposal site (known as "waste disposal"), and the disposal of industrial effluent or water containing waste (known as "effluent discharge"), usually into a water body. This differentiation was due to the fact that separate legislative tools regulated the disposal of waste onto land and the discharge of industrial effluent. The discharge of water containing waste (liquid waste or effluent) was governed in terms of s21 of the Water Act 54 of 1956. The disposal of waste onto land is regulated in terms of s20 of the Environment Conservation Act73 of 1989. This differentiation was based largely on the origin of, and amount of moisture in, the waste, and the higher the moisture content, the more likely the effluent would be regarded as suitable for discharge into a body of water.

The decision regarding where to dispose of waste was in many instances not based on whether an option was the most sustainable with which to manage the waste, but was based solely on a cost evaluation made by the industry that generated the waste. However, because of increased treatment costs as water quality requirements became more stringent, many effluents containing offensive chemicals were not treated for discharge into a body of water, but were disposed of untreated in waste disposal sites. This resulted in the disposal of large volumes of waste with high moisture content on land in waste disposal sites, when such waste should have been treated, and the purified effluent returned to the water resource. This practice increases pressure on waste disposal sites, risk to that portion of the water resource found in the ground underneath these sites, and affects the stability and integrity of the design of the sites themselves.

The Constitution of South Africa Act 108 of 1996 resulted in the promulgation of new environmental legislation for South Africa. On the basis of s24 of the Constitution, a review of all existing water legislation was launched by the Department of Water Affairs and Forestry (DWAF), a process which resulted in the publication of the *White Paper on a National Water Policy for South Africa* (DWAF, 1997a). The countrywide adoption of this policy document culminated in the promulgation of the National Water Act 36 of 1998 (NWA). One of the basic concepts on which the NWA is founded, is the fact that the "*water resource*" is defined in terms of the indivisibility of the hydrological cycle (Stein, 1999:8). This means that the water resource includes watercourses, surface water, estuaries, and aquifers, which must be managed in an integrated manner. In the NWA, the term "*pollution*" is defined for the first time in relation to the water resource, and the Act also contains an extended definition for the term "*waste*", which encompasses most sources of waste. These definitions are therefore more comprehensive than those under any previous or other existing legislation:

> ***"Pollution"*** *means the direct or indirect alteration of the physical, chemical or biological properties of the water resource so as to make it –*
> ***(a)*** ***less fit for any beneficial purpose*** *for which it is or may reasonably be expected to be used; or*
> ***(b)*** ***harmful or potentially harmful –***
> *(aa) to the welfare, health or safety of human beings;*
> *(bb) to any aquatic or non-aquatic organisms;*
> *(cc) to the resource quality; or*
> *(dd) to property.*
>
> ***"Waste"*** *includes any* ***solid*** *material* ***or*** *material that is suspended, dissolved or transported* ***in water*** *(including sediment) and which is spilled or deposited* ***on land or into a water resource*** *in such volume, composition or manner* ***as to cause, or to be reasonably likely to cause****, the water resource to be polluted.*

The disposal of water containing waste into a surface water resource holds the potential risk of polluting (mainly) that surface water resource. The disposal of waste, or water containing waste, on land holds the potential to pollute also (mainly) the ground water component of the water resource. Both these actions are listed as **water uses** under s21 of the NWA, which will be authorised by the NWA, provided that such use is sustainable. This implies that there is a difference between "pollution" and "sustainable use". The mechanisms previously and currently applied to determine potential risk to a water resource when water containing waste is discharged to surface water, as well as when waste is deposited on land therefore need to be revisited in order to determine whether they provide for the above-mentioned distinction, as required in the NWA.

1.2.1 CURRENT APPROACHES

Two procedures are currently used to determine potential risk to a water resource and to make decisions regarding the acceptability of such risk:

To deposit **water containing waste** originating from an industry **into a water resource**, an application for an exemption from s21(1) of the Water Act 54 of 1956, had to be made by the generator of the waste. A certain procedure, described in the document: *"Procedures to assess effluent discharge impacts*" (DWAF, 1995), had to be followed in such an application to determine whether such a discharge would render the resource less fit for any beneficial use. This procedure involves a systematic process for determining whether the discharge can be prevented, and ensuring, if it can not, that the quality of the water discharged complies either with the quality requirements of the downstream users (Receiving Water Quality Objective (RWQO) approach) or with the Effluent Standards published in the Government Gazette (RSA, 1984). If the effluent does comply with these requirements, it can be discharged, and this is viewed as a beneficial non-consumptive use of the water resource. If it does not, such discharge would be regarded as pollution, and the water containing waste must either be treated or be managed in some other way.

When **waste** or **water containing waste** is deposited **on land**, the ground water component of the water resource is potentially placed at risk, and the person in control of the area where the waste is to be disposed of requires a permit from the Department of Water Affairs and Forestry (DWAF) in terms of s20(1) of the Environment Conservation Act 73 of 1989 (ECA). The procedure for applying for such a permit is described in a series of documents published by DWAF, which are collectively known as the "Minimum Requirements" documents. The documents contain details of the selection, design and management of different types of waste disposal sites. Also contained in these documents is a waste classification system, which is aimed at determining the harmfulness of waste streams, with regard to both the safety and health of humans and the potential hazard it poses to the environment when such waste is disposed of on land (e.g in a waste disposal site). A permit thus normally contains a condition stipulating that only waste classified as acceptable in terms of the "Minimum Requirements for the handling, classification and disposal of hazardous waste" (DWAF, 1998b), may be disposed of at the specific waste site for which the permit is issued. This classification procedure contains a mechanism for determining potential risk to the environment when the waste is disposed of, and the potential risk it poses to the environment, particularly the ground water resource, may be sufficient reason for it to be classified as hazardous. The disposal of waste classified as hazardous into a site which is not designed to accept this type of waste is regarded as pollution, and would be a contravention of permit conditions. The "Report on Hazardous and Related Waste", which forms part of the Situation Baseline Analysis Phase of the National Waste Management Strategy (NWMS) Project (DWAF, 1998a:49) identifies a number of important pilot projects. It concludes that one of these studies should be aimed at establishing an integrated system that addresses waste from all sources, both hazardous and non-hazardous. It also recommends that the study should include an ...*evaluation of the (existing) approach as applied to the disposal of hazardous (and non-hazardous) waste, the identification of possible clean-up and remediation goals and the development of approaches to remediation....*

1.2.2 PROBLEM STATEMENT

From the above, it is clear that two separate mechanisms exist for determining potential risk of pollution of the same water resource, although it is regarded as indivisible under the NWA. Not only do the procedures differ, but the information required to determine potential hazards and risks is also different. These differences could have the effect that conflicting decisions are taken about the same waste stream, especially with regard to whether to discharge water containing waste into a river, or to deposit it on land, for example in a waste disposal site.

It is therefore necessary to evaluate these existing regulatory and administrative mechanisms aimed at determining the lawfulness of the disposal or discharge of a waste into the environment, in terms of their applicability to the NWA of 1998, i.e. the effectiveness with which they distinguish between sustainable use and pollution. This evaluation will aim to determine whether sound environmental management principles are being followed, and whether they can be used as environmentally sound decision-making tools to determine if a discharge or disposal action does, or could, involve the risk of pollution, or whether such an action is a beneficial use of the resource. In the event that the evaluation reveals problems that could cause difficulty with the implementation of the NWA, it will also determine how to incorporate these two mechanisms into a harmonised procedural approach that can be used for decision-making under the NWA.

1.3 AIMS OF THIS STUDY

The objective of the study is to evaluate current mechanisms used to distinguish between beneficial use of the resource and pollution of the resource, as environmental management tools, by –

- Discussing the concepts and principles of sustainability, pollution, and integrated waste management;
- Discussing and investigating the impact of and risks associated with waste disposal and discharge, and the current legislation aimed at managing these risks, to determine the requirements for an assessment tool for making decisions about these actions, from the perspective of risk assessment and risk management, and in the context of integration and harmonisation;
- Evaluating the two existing procedures for determining potential risk to the water resource in terms of sustainability principles, legislative requirements and risk management perspectives; and
- Suggesting an integrated procedure for determining potential risk to the water resource when waste or water containing waste is disposed of in a manner which could affect the water resource.

1.4 SCOPE AND LIMITATIONS OF THIS STUDY

This study focuses mainly on evaluating the procedural approaches that were developed before the promulgation of new legislation in terms of their effectiveness in determining environmental risk, i.e. their success in distinguishing whether disposal or discharge of waste will be a sustainable use, or pollution of the environment. Although the implementation of an effective approach will lead to waste minimisation, the focus is on the action of disposal or discharge of waste and its effects.

The study is undertaken from the perspective of the field of management science, particularly environmental management at macro-level. Other scientific disciplines, such as geohydrology, geology, civil design engineering, chemistry, microbiology and toxicology, influence the integrated management of waste and water resources, and particularly the sustainable disposal and discharge of waste. Where necessary, specialists in these disciplines are referred to, but in the space available it is not possible to go into all these fields in great depth. Furthermore, the detailed chemistry and toxicology of different elements and their pathways in, for example, humans, animals, air and water, are beyond the scope of this investigation.

1.5 METHODS OF INVESTIGATION

A qualitative research method is employed, supporting the hermeneutic approach to science. This means that an understanding of the problem is firstly developed by a review of the literature on the principles of sustainability and waste management, as well as the science of environmental risk analysis and the discussion of new legal requirements. Secondly, current processes for and approaches to determining the acceptability of a waste disposal action are evaluated in terms of these principles and new legal requirements and, where available, the viewpoints, perceptions and controversial arguments of role-players, in order to synthesise a finding regarding these facts and perspectives. During this evaluation, implications of principles, relationships between viewpoints, inadequacies in approaches and shortcomings in conclusions are indicated in order to arrive at a recommendation that endeavours to address these implications and problems.

A study of the relevant literature proved useful in some of the areas covered. However, there is very little literature on some of the topics discussed, because of some recent developments in the field, such as the promulgation of new legislation. The available literature, as well as the author's experience in the fields of environmental management, water quality management and waste management (specifically with regard to the evaluation of waste classifications and the rehabilitation of contaminated areas) contributed to the practical evaluation of the current approaches, and lead to the suggested improvements.

1.6 STUDY LAYOUT

Chapter 1 accounts for the problem statement and the aims of the study, as well as its scope and limitations, and provides the layout of the document.

In **Chapter 2** theoretical issues regarding the principles of sustainability and the concept of pollution, as well as the internationally accepted hierarchy of options for waste management are introduced.

In **Chapter 3,** the different components influencing risk associated with waste disposal or discharge, namely source, pathway and receiving environment, as well as measures aimed at reducing risk, are investigated. The recent legislative developments aimed at protecting the environment, specifically the water resource, against these risks, are introduced, before the scientific principles and components of risk analysis and its applicability to regulatory assessment and decision-making are discussed from the perspective of risk harmonisation.

In **Chapter 4,** evaluation criteria are deduced on the basis of the practical implications of the principles of sustainability. The two different approaches currently used in South Africa to determine the acceptability of a disposal or discharge action are then described and evaluated according to these criteria.

In **Chapter 5**, the findings reached in the preceding chapters are used to develop an integrated decision-making framework, based on environmental risk analysis and in accordance with the regulatory requirements that distinguish between sustainable use and pollution. This framework is discussed in terms of its applicability to various problem areas in waste and water resource management.

Lastly, **Chapter 6** contains final conclusions reached during the study and makes recommendations with regard to the findings of the investigation.

1.7 SUMMARY

The advent of increased environmental awareness during the latter part of the twentieth century has raised some interesting questions, and is leading to some enormous changes in perceptions. Since waste has always been, and still is, ultimately disposed of in the environment to be "forgotten forever", modern environmental management thinking requires that the risks to the environment resulting from such disposal be quantified in an integrated manner. The effectiveness of the existing assessment mechanisms as environmental risk assessment tools in terms of the NWA is assessed in this study on the basis of current environmental management and waste management principles, and suggestions towards a integrated regulatory framework are made.

CHAPTER 2: PRINCIPLES OF SUSTAINABLE WASTE MANAGEMENT

2.1 INTRODUCTION

One of the inescapable consequences of the laws of nature, as formulated elegantly in the Second Law of Thermodynamics (Atkins, 1984:136), is that no process can ever be 100% efficient. **Waste** is defined as any undesirable or superfluous by-product, emission or residue of any process or activity, which has been discarded, accumulated, or stored for the purpose of discarding or processing (DWAF, 1998b:G-8). Waste is generated in all processes that transform materials from one state to another. In a best-case scenario, only waste energy is produced, but usually some form of matter, for which there is no further use for the current user, is generated or produced. Moreover, in addition to waste generated during the production of a product, the product is often accompanied by packaging or other material which does not leave the production process as waste, but which does enter the waste stream at some later point (Law, 1996:100).

Wastes are the solid, liquid or, occasionally, gaseous by-products that must be accommodated in the environment in a manner that will be sustainable. Some wastes may be recycled or treated and concentrated and disposed of on land or incinerated. Wastes with a high moisture content (effluent) are normally treated and piped into a water resource (discharged), but are often also disposed of on land (disposal), sometimes along with wastes of lower moisture content (co-disposal), while gaseous wastes are mostly vented into the atmosphere (emission). These actions have the potential to lead to environmental deterioration or damage, and the extent of this potential depends on the intrinsic hazards posed by the waste, the pathways by means of which these hazards may be realised, and the potential recipients at the end of these pathways. This implies that measures should be implemented to reduce the possibility of these risks being realised, and the decision regarding the most suitable management option to be implemented must be determined from the perspective of sustainability, which requires that waste must be managed in such a manner that pollution is prevented. Therefore, in this chapter, current international thinking regarding the principles of sustainability and the concept of pollution are explored, and the management of waste in an integrated and sustainable manner is discussed.

2.2 THE CONCEPT OF SUSTAINABLE USE

The concept of "sustainability" should not be confused with that of "sustainable development". Equity is both temporal and intergenerational. Temporal equity is the present fairness of policies and actions, and refers to the equity between, for example, race and gender. **Intergenerational equity,** or equality between generations, is the ultimate moral principle behind the notion of sustainability, since its goal is the maintenance of natural resources for future generations (Geisler, 1981 in Rickson & Rickson, 1990:107). **Sustainability** is therefore the long term and difficult aim of reaching a sustainable ecological state of equilibrium, whereas the variable and as yet poorly-defined process by which this goal is to be achieved is called **sustainable development** (Dovers and Handmer, 1993:217). In 1987, in the Report of the World Commission on Environment and Development (WCED), which is now referred to as the Brundtland Report, sustainable development was defined as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Gardner, 1989:338; Robinson, 1996:20 and others).

The world-wide initiative: *Caring for the earth, a strategy for sustainable living*, which was launched during 1991 in a partnership between the United Nations Environment Programme, the World Wide Fund for Nature and the World Conservation Union, asserts that "to live sustainably depends on accepting a duty to seek harmony with other people and with nature. . . . Humanity must take no more from nature than nature can replenish" (Fuggle and Rabie, 1994:2). This means that any "use" of the environment must take place in a manner that will be sustainable. The terms "sustainable development" and "sustainable use" are used interchangeably, although "development" more often refers to a new action or the expansion of an existing activity, whereas "use" refers to all actions, existing or proposed, that have or may have an impact on resources. When a natural resource is utilised in such a manner that the functioning of its systems is not compromised, but rather maintained in such a manner that future generations can share the same quality of life as the present generation, this is referred to as "**sustainable use**". Of particular note in this approach are:

- The holistic approach to the environment. Reduction of pollution in one medium, such as air, may not take place at the expense of another, such as ground or surface water.
- The emphasis on a long-term solution, implying that there should be no bad legacy for the next generation, which re-iterates the concept of sustainability.
- The consideration of all alternatives in order to implement the best alternative (also known as the Best Practical Environmental Option (BPEO)), as illustrated below (adapted from Law, 1996:101):

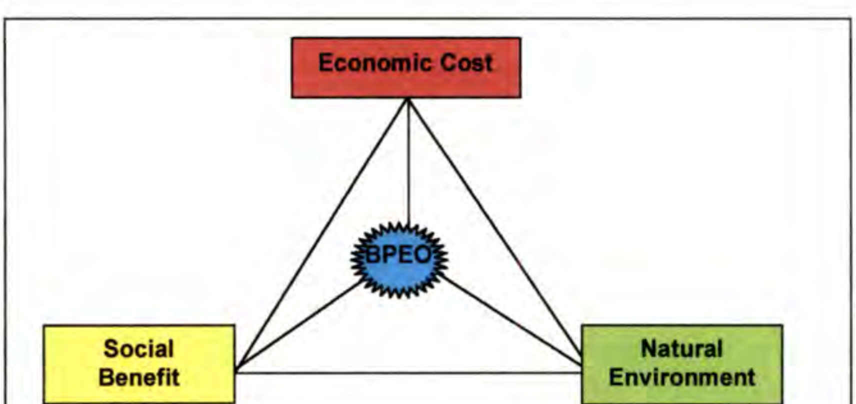

Figure 1: Schematic presentation of the establishment of the Best Practical Environmental Option

According to Fuggle and Rabie (1994:51), one of the great environmental and economic tasks facing South African policy-makers is to identify levels of maximum sustainable yield for renewable resources. In order to achieve the goal of sustainability, any proposed action should past three tests: it should be 'a sustainable use', it should close the 'income gap' and it should maximise the net benefits from resource use, i.e. 'be efficient'. Environmental management is aimed at achieving this goal of sustainability, a concept which can be described as a state of equilibrium between the demands placed by man on natural resources, and the ability of these resources to assimilate such demands without compromising the functioning of their systems.

2.2.1 PRINCIPLES OF SUSTAINABLE ENVIRONMENTAL MANAGEMENT

When the development and use of natural resources have to be managed in such a manner that they are environmentally sustainable, several initiatives and specific management processes must be implemented. Such initiatives and management processes have been developed over the latter part of this century, and are known as "environmental management" processes. In this context, the term **environment** is used in its broadest form, and includes biophysical, social, economic, historical, cultural and political aspects. Environmental management should not be confused with the management (manipulation) of the natural environment (nature conservation and the management of plants and animals), but must be seen as the management of man's activities within the carrying capacity of environmental systems.

Gilpin (1996:170) states that:

> "Environmental management is a **concept of care** applied to individual premises, corporate enterprises, localities, regions, catchments, natural resources, areas of high conservation value, lifetime cycles, **waste handling and disposal**, cleaner processing and recycling systems, with the purpose of protecting the environment in the broadest sense. It involves the identification of objectives, the adoption of appropriate mitigation measures, the protection of ecosystems, the enhancement of quality of life for those affected, and the minimisation of environmental costs".

The overall goal of environmental management from a sustainable development perspective is to minimise safety, health and environmental impacts, while at the same time optimising economic, social and psychological impacts on society (Asante-Duah, 1993:9). Environmental management initiatives on the international, political and administrative levels are often referred to as macro-environmental management, and environmental management approaches on the business level are referred to as micro-environmental management. However, since both macro- and micro-environmental management are aimed at the same goal, namely sustainability, the environmental management initiatives on these different levels share certain basic principles.

Principles for environmental management at a **macro-level** originated from international initiatives, such as the *Caring for the Earth* initiative (Fuggle and Rabie, 1994:2,3) referred to above, the principles set out in the Rio Declaration (UNCED, 1992) and Agenda 21 (DEAT, 1998a). In South Africa, macro-environmental management principles are incorporated into the National Environmental Management Act of 1998 (RSA, 1998b), as well as the Integrated Environmental Management (IEM) procedure (DEA, 1992a:5) and the "Fundamental Principles and Objectives for a New Water Law in South Africa", which were approved by Cabinet in November 1996 (DWAF, 1997a:3, 34-36) and which includes the principles of the Integrated Catchment Management (ICM) approach (DWA, 1986:6.65-6.67 and DWAF, 1996a) as adopted for the management of the water resources of the country according to the recommendations of Agenda 21 (DEAT, 1998a:35).

Some of the initiatives for the implementation of environmental management at micro-level can be found in the International Chamber of Commerce (ICC) Business Charter for Sustainable Development (ICC, 1991 and SABS, 1996b:28), and the Responsible Care programme supported by the South African Charter of the Chemical and Allied Industries Association (CAIA) (CAIA, undated). The international standard that specifies the requirements of an environmental management system, ISO14001, is intended to provide businesses with the elements of an effective system that will assist in the achievement of environmental and economic goals (SABS, 1996a:v and SABS, 1996b). Table 1 below indicates the extent to which the above-mentioned initiatives and systems at macro- and micro-level share certain principles. This table does not list all the individual principles of each initiative, approach or system, but merely states whether the above-mentioned shared principles are included or implied in the make-up of the initiative, approach or system.

Table 1: Principles of different international initiatives directed towards Sustainable Development

	Initiatives at a macro-level				Initiatives at a micro-level		
Initiative	Caring for the Earth	Rio declaration & Agenda 21	NEMA and IEM	Water Management & ICM	ICC Business Charter for sustainable development	Responsible Care (CAIA)	ISO 14001
Principles							
Precautionary approach	Included	Included	Included	Implied	Included	Included	Included
Polluter pays principle	Included	Included	Included	Included	Implied	Implied	Implied
Cradle to Grave	Implied	Implied	Included	Included	Included	Implied	Included
Integrated and Holistic	Included	Included	Included	Included	Included	Included	Included
Consideration of Alternatives	Included	Implied	Included	Included	Included	Not stated	Not stated
Carrying capacity	Included	Included	Included	Included	Included	Not stated	Not stated
Continuous improvement	Included	Included	Included	Implied	Included	Included	Included
Accountability and Liability	Included	Included	Included	Included	Implied	Implied	Included
Transparency & democracy	Included	Included	Included	Included	Included	Included	Included

According to this comparison, the following general principles of environmental management are shared by the political, administrative and economic sectors of society:

Table 2: Shared Principles of Sustainability

Principle	Description
The **Precautionary** approach	This is a pro-active principle aimed at avoiding environmental impact before it occurs, and has the purpose of preventing pollution. Principle 4 of the Rio Declaration states that environmental protection is an integral part of the development process, and cannot be considered in isolation.
The **Polluter Pays** principle	This principle maintains that the polluter should bear the full cost of any damage caused to the environment, and entails the internalisation of external costs. This implies that resource economics should be employed to ensure that the market price of a commodity should reflect environmental costs, threats, risks and liabilities.
The Cradle to Grave principle	This principle implies that there is "No away", and that the impacts of actions should be managed throughout project, product and/or service life cycles, from reconnaissance and conception to rehabilitation and aftercare.
The principle of an **Integrated and Holistic** approach	The extended definition of "environment" is supported by this principle and entails an integration of traditional scientific realms and a holistic approach to the management of potential impacts on the environment.
The principle that due consideration must be given to all **alternative options.**	The most sustainable option, known as the **Best Practical Environmental Option** (BPEO) should be implemented. The BPEO is defined by the British Royal Commission on Environmental Pollution as "the outcome of a systematic consultative and decision-making procedure that emphasises the protection of the environment across land, air and water. It establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole at acceptable cost in the short as well as long term" (Hawkins, 1996:12). The BPEO is the option that will balance long term economic, environmental and social concerns (see Figure 1 page 9, and Figure 3, page 17).
The **Carrying Capacity** principle	This principle is aimed at ensuring that development does not exceed the natural carrying capacity of environmental systems, and forms the basis of the selection of the BPEO. This concept is discussed in more detail in section 2.3.1 on page 13.
Continuous Improvement	This principle underpins environmental management systems such as ISO14001. It implies that managers will continuously implement measures to improve their systems, goods and services, and make them more eco-efficient by reducing resource consumption and waste generation through good housekeeping practices or "due diligence". Thus, fewer resources will be used to achieve better products and services, and less waste will be generated. The continuous improvement principle furthermore implies that as our knowledge of environmental systems improves, we should improve the mechanisms by means of which we manage the environment. This means that decision-making should be based on the best available scientific knowledge.
Accountability and Liability	This principle implies firstly that line function managers are criminally liable for actions causing pollution or damage to the environment. It implies secondly that there must be accountability for information provided and for decisions that may have an effect on the environment, and, thirdly that a clear cut-off point must be set to define pollution.
Transparency and Democracy	This principle suggests that the people whose environment will be affected by a decision or action should be given the opportunity to be involved in such a decision, and that the manner in which decisions are taken should be transparent and reasonable.

These principles therefore enjoy wide acceptance, in international, legislative and economic circles, as the general principles involved in achieving sustainability, and they will be applied practically in Chapter 4 to deduce the criteria for the evaluation of existing mechanisms used to control waste disposal and discharge. In order to determine their practical implications, it is necessary to explore the concept of "pollution" in the context of the principles of sustainability as introduced above, especially the carrying capacity principle.

2.3 THE CONCEPT OF "POLLUTION"

Weale (1992:3) suggests that the scientific definition of pollution is a hotly contested issue. Wastes are the unwanted by-products of human activity and may contain substances that, if not effectively controlled, can cause harmful pollution. According to Hawkins (1996:9), Asante-Duah (1993:8), Fuggle and Rabie (1994:592) and others, all substances and wastes are potentially hazardous, since almost any chemical could cause severe health impairment or even death if taken into the body in sufficiently large amounts. Almost all human activities result in the production of some substance and, as stated above, all chemical substances can be considered as potential pollutants of the environment. However, waste may also contain components which, although unwanted for one type of activity, are regarded as a resource for another activity or sector of society. Therefore, waste must be managed and pollution must be prevented in order to achieve sustainability. According to Blowers (1994:72) and Law (1996:100), waste may or may not be harmful depending on the circumstances under which it is managed. Since it is the combination of the characteristics of the waste and these circumstances that will determine whether or not an action causes pollution, it is necessary to explore this combination in the context of the principle of carrying capacity.

2.3.1 CARRYING CAPACITY

According to Weale (1992:3), substances introduced into the environment in quantities or concentrations greater than those that can be coped with by the cleansing and recycling capacity of nature, constitutes pollution. This idea of "carrying capacity" or "environmental capacity" or "assimilative capacity" has wide acceptance in discussions on sustainable development, and is a concept that implies that there is a limit on the capacity of the environment to "absorb" some form of activity, e.g. a population of people (Farmer, 1997:5). For the introduction of pollutants into the environment, this means that the receiving environment might accumulate these pollutants to a point where adverse effects occur, and this point, or "critical value", is determined by various critical factors, not only the concentration of the most harmful substance in the waste. Farmer (1997:18) summarises by stating that carrying capacity is the ability of the environment to absorb contaminants without adverse impacts, and is the basis of concepts such as "critical loads". A good example is the use of artificial wetlands for the treatment of waste water with high salt content. Over time, the accumulation of the salts may exceed the capacity of the wetland system to assimilate them, and they will start to leach from the wetland, so that it no longer performs its function, but acts as a source of pollution. To ensure the sustainable functioning of the wetland, the introduction of the salts must be controlled and kept within its carrying capacity. Moreover, different ecological and environmental systems may not have the same capacity to carry or "assimilate" pollutants. For example, soils such as limestone or chalk may have an almost unlimited ability to deal with acid deposits, and therefore have a high carrying capacity for incoming acidity, whereas rocks such as granite do not possess this capacity at all (Farmer, 1997:5).

The concept of "carrying capacity" means that there are finite limits to the ability of the earth's ecosystems to "assimilate" pollutants. To keep the effects of man's activities within these limits is one of the basic principles when working towards sustainability. According to Gardner (1989:341), adherence to the second substantive principle for sustainable development, namely the maintenance of ecological integrity, depends on staying within the limits of ecological carrying capacity by promoting ecologically realistic consumption or use standards. The discussion above suggests that staying within the carrying capacity does not depend only on the characteristics of the waste, but also on the ability of the receptors in the environment to deal with these characteristics.

2.3.2 DEFINING RISK AND POLLUTION

In order to determine what is effectively meant by "**pollution**" in the context of sustainability and integrated environmental management, it is necessary to establish the definitions of **hazard**, **harm**, **exposure**, **risk,** and **pollution,** since the vocabulary of the subject suffers from two particular difficulties, namely:

- it appears non-technical because its terms are used in everyday speech; and
- numerous groups of specialists who are involved in environmental management, have assigned their own definitions to certain terms (United Kingdom Department of Environment (DoE), 1998:3-5).

(Some additional definitions on the subject are included in the Glossary of Terms.) According to Asante-Duah (1993:21) and Hunt (1998:xii), a **hazard** is defined as a substance, object or situation that, in particular circumstances, can lead to **harm**, i.e. has the potential to have an adverse impact on people, the environment, and/or property. It represents the unassessed loss potential and may comprise a condition, a situation, or a scenario with the potential for undesirable consequences. The degree of hazard will usually be determined by the **exposure scenario** and the potential effects or responses resulting from any exposures. Figure 2 below (from Bennet in Kamrin, 1997:43) illustrates some exposure scenarios.

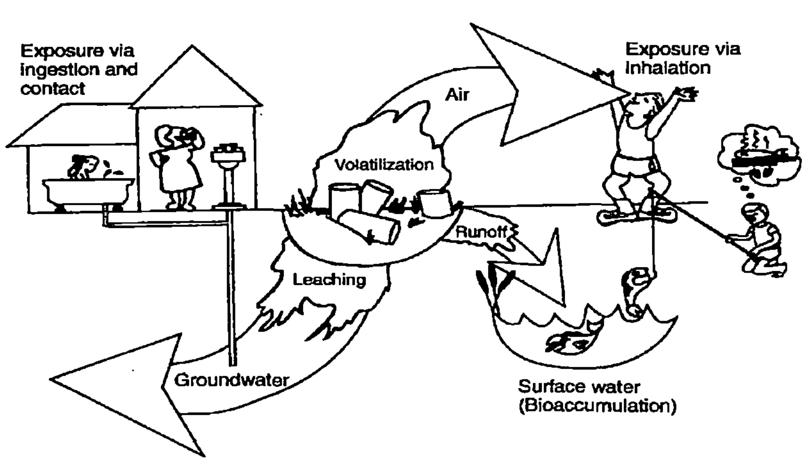

Figure 2: Pathways exposing receptors as a result of an uncontrolled waste disposal on land (source)

From this Figure, it is clear that a **risk** is posed when there is a **source**, a potential exposure **pathway**, and a **receptor** (receiving environment, i.e. ecosystems and/or humans: the so-called "population at risk"). In developing an understanding of the concept of pollution, it is important to note that risk is not a concentration, dose, other value based point, or even non-value based levels. **Risk** is the probability that a particular adverse effect occurs during a stated period of time, **e.g. the probable number of deaths in a population resulting from an action or situation** (such as discharging or disposing waste or water containing waste onto land or into a water resource) for the duration of that action (Hunt, 1998:xiii). Some risk levels from "normal" human activities are listed in Table 3 below (Asante-Duah, 1993:32, Grasso, 1993:L-11).

Table 3: Perspective on risks associated with normal human activities

Risk of Death	Occupation	Lifestyle	Accidents	Environmental circumstances
1 in 100 (10^{-2})	Stuntman, Race car driver			
1 in 1000 (10^{-3})	Miner, Fireman, Policeman	Smoking (1 pack a day)	Skydiving, Canoeing, Rock-climbing	
1 in 10 000 (10^{-4})	Banker, Engineer Farmer	Heavy drinking	Home accidents, Driving motorcars, Frequent air travel	
1 in 100 000 (10^{-5})	Truck driver	Using contraceptive pills, Light drinking	Home fires, skiing	Living downstream from a dam
1 in 1 000 000 (10^{-6})	Insurance agent	Diagnostic X-rays, Smallpox vaccination (per occasion)	Fishing, Poisoning with home chemicals	Drinking clean/natural water, Natural background radiation
1 in 10 000 000 (10^{-7})		Drinking 30 cans of diet soda containing saccharin (in a lifetime), Eating charcoal-broiled steak (once a week)	Occasional air travel (once a year)	Living at the boundary of a nuclear power plant, Hurricane, Tornado, Lightning, Animal Bite, Insect sting

Taking these complexities into consideration, it may rightly be concluded that there is no escape from risk, no matter how remote, and that there are only choices among risks (Daniels, 1978 in Asante-Duah, 1993:31). Although the popular concern is focused on those chemicals that will cause ill effects to humans in small doses (known as "toxic chemicals"), the effects of other substances, which are not necessarily harmful to humans, must also be considered, since they could pose a hazard to some component of the environment. In some instances the cumulative effect from these substances may pose an even greater long-term risk than the risk posed by small quantities of "toxic" chemicals.

According to Fuggle and Rabie (1994:617), it would be virtually impossible to reduce all environmental exposures to pollutants to a level where the risk to the health of the human population was zero. Weale (1992:3) supports this view, stating that pollution is the introduction into the environment of substances or emissions that either **damage**, or carry the risk of damaging, human health or well-being, the built environment or the natural environment. This then implies that substances can be introduced into the environment without potential or actual damage to human health or well-being, the built environment or the natural environment. Farmer (1997:3) agrees with this, stating that a released substance can be safely introduced into the environment, but that when it causes harm or poses a risk, it is a pollutant. Westlake (1997:454) goes even further by saying that while environmental pollution must be prevented, the prevention of introduction of substances into the environment might not be possible. This implies that the artificial introduction of substances into the environment could be considered as "use", and that only when the level of exposure reaches a certain limit, this contamination will be considered "pollution". In this instance, it is important that the concepts of risk and acceptable risk must be clearly understood.

Risk may therefore be seen as the probable occurrence of an adverse effect, or an assessed threat to persons, the environment, and/or property, due to some hazardous situation or owing to a systems failure. It is often expressed as a measure of the probability and severity of adverse consequences, of exposure for potential receptors. It may be represented simply by the measure of the frequency of an event. Risk represents the assessed loss potential, often estimated in terms of the mathematical expectation of the consequences caused by the occurrence of an adverse effect. The product of the two components, namely the probability of occurrence (*p*) and the consequence or severity of occurrence (*S*), is used to define this (Keller, 1992:76 and Hawkins, 1996:9), viz: $\textit{Risk} = p \times S$. Hunt (1998:48) states that this definition often creates confusion, in that it postulates a risk that can be exactly determined, leading to the comparison of different events with different outcomes, which is not possible in a mathematically meaningful way. Asante-Duah (1993:22) agrees, and uses a different relationship, stating that the level of risk depends on the degree of hazard as well as on the amount of safeguards or preventative measures against adverse effects, and consequently defines risk by using the following conceptual relationships:

$$\textit{Risk} = \frac{\textit{Hazard}}{\textit{Preventative Measures}}$$

Or:

$$\textit{Risk} = f\,(\textit{Hazard, Exposure, Safeguards})$$

In this context, "hazard" will refer to the properties of the waste and "exposure" to the vulnerability of the receiving environment or environmental conditions, while "preventative measures" or "safeguards" are considered to be a function of the effectiveness of management measures aimed at risk-reduction. Blowers (1994:72) agrees with this, and also recommends that, where waste contains materials that are or could be harmful to human health or the environment, there should be a procedure for determining risk based on the degree of hazard, the vulnerability of the environment, and the appropriate methods of management.

The reduction of hazards by the implementation of preventative measures will generally result in the increase of production costs, and cost minimisation during hazard abatement will most likely leave higher degrees of unmitigated hazards. Managing substances with the potential to hold a risk of harm therefore involves competing objectives (Asante-Duah, 1993:35). The relationships between cost, hazard and risk are illustrated in Figure 3 below (adapted from Asante-Duah, 1993:35 and WRC, 1999:2-3).

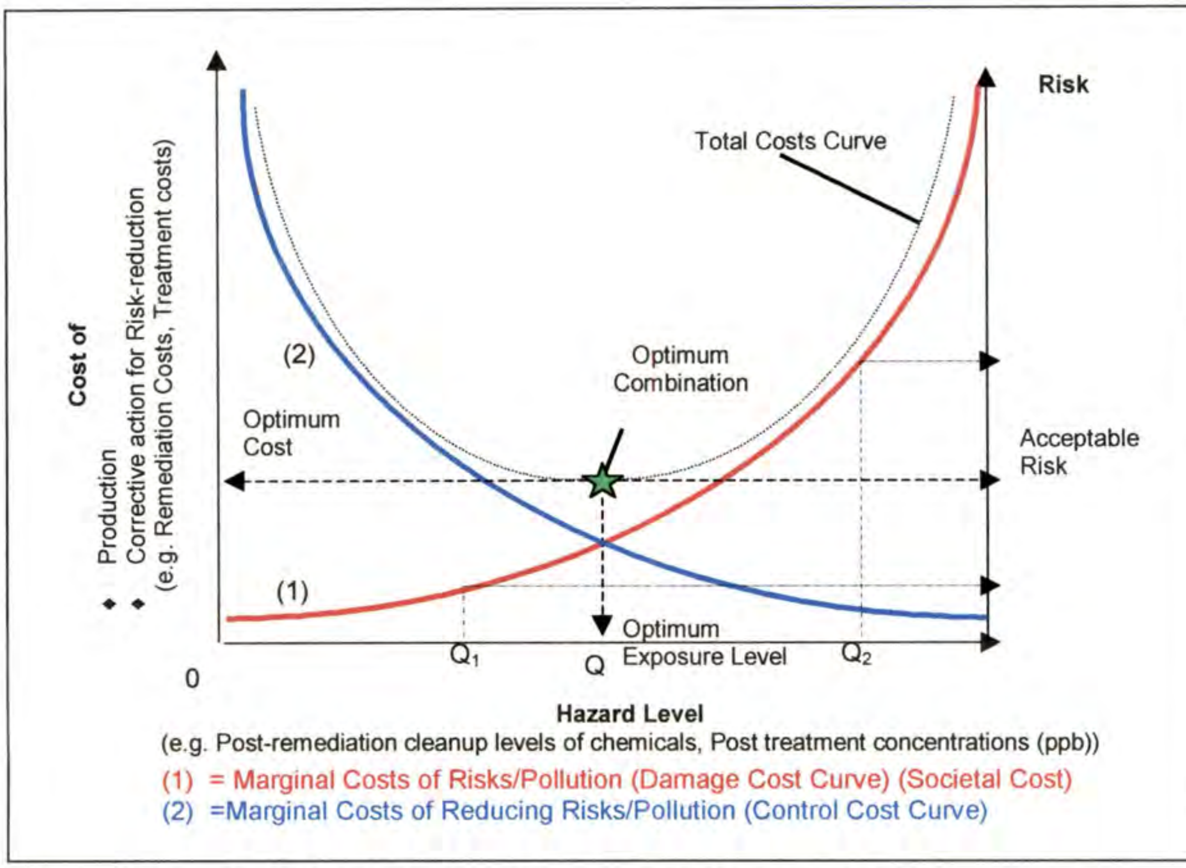

Figure 3: Optimum level of contamination in terms of acceptable risk and economic activity

This figure shows that as the level of a substance introduced into the environment as a result of industrial activity increases, so does the cost to society of the hazard posed by the substance. Also, the more money spent on controlling the effects of the substance, the less the risk of harm resulting from the release of the substance. At point Q, where the curves intersect, control costs are equal to damage costs (WRC, 1999:2-3). This point depends on the level of risk that is acceptable to society. The figure also shows that the optimum combination of acceptable risk, damage costs and control costs, results in an optimum exposure level (Q), which is not equal to zero. Contemplating this from a different angle, the implication is that the production cost of a commodity may not be billed to society or the environment, in accordance with the **polluter pays principle (internalisation of external costs)**. Since damage to the environment does not occur in financial year brackets, but over decades, the costs associated with environmental repair will be difficult to estimate. Because of this, as well as the fact that the cost of repair is always much higher than the cost of prevention, the **precautionary principle** must be applied. Owing to the fact that there are always hidden costs, as well as to the incorporation of the precautionary principle, the total cost curve at the optimum exposure level will be somewhat higher than the exact cost where the two curves intersect.

From the equations, illustration and discussion above, it is clear that in order to determine whether an existing action or proposed activity is, or could be polluting, an acceptable risk needs to be laid down by a controlling authority representing civil society, and the actual risk or hazard posed by the action or activity must then be determined and compared to that acceptable risk.

2.3.2.1 ACCEPTABLE RISK

From Figure 3 it can be deduced that, if a substance is present at a concentration Q, the exposure to a hazard will be considered to be at an optimum level when the risk is deemed "acceptable". According to Asante-Duah (1993:32) and Hunt (1998:31), considerable controversy surrounds the concept of acceptable risk, since, in practice, acceptable risk is the risk associated with the most acceptable **decision** – rather than being the most acceptable in the absolute sense. It has been pointed out (Massman and Freeze, 1987 in Asante-Duah, 1993:32) that acceptable risk is decided in the political arena, and "acceptable risk" actually means "politically acceptable" risk. Typically, risks of premature death below the level of one in one million (i.e. 10^{-6}) will be considered acceptable in regulatory circles, since this compares favourably with risks from "normal" human activities (See Table 3 above). (It must be noted that an "acceptable risk" can never be measured in concentration units, since it relates to risk of death or damage.) The selection of a concentration or exposure level that can be regarded as acceptable (optimum exposure **level**) thus depends on the nature of the risk, the stakeholders involved, and a host of other contextual variables, such as the other risks it is being compared to. Unless an "acceptable risk" is fixed by political decree and a method for determining these optimum exposure levels is established, Asante-Duah (1993:33), states that optimum exposure levels will be both fuzzy (in that they cannot be precisely specified) and relative (in that they will depend on specific circumstances). It has long been recognised that nothing is either wholly safe or wholly dangerous per se, but that the object involved and the circumstances, manner and conditions of use determine the degree of hazard or safety (Asante-Duah, 1993:31). Fuggle and Rabie (1994:617) also assert that, in managing environmental hazards, an acceptable level of risk of morbidity and mortality needs to be set. This is particularly important when dealing with the regulation of carcinogenic substances, for which there may be no threshold of safety. The development of a prudent policy on acceptable levels of exposure is therefore important. Such a policy should, however, always be revised and updated with new scientific knowledge, which in some cases may lead to more stringent measures, or may show that some measures have been unnecessarily restrictive.

The optimum exposure level, i.e. the **value** of Q, measured in the applicable units of the relevant hazard criterion, is determined from the acceptable risk. In the United Kingdom, this level is known as the maximum exposure level (MEL), and the United States of America use the NOAEL (No Observed Adverse Effect Level), and ALARA (As Low as Reasonably Allowable) (Asante-Duah, 1993:86). In the development of such levels, a multi-media and multi-disciplinary approach must be adopted, as many problems and discharges are not limited to a single medium such as the air, water or soil (Fuggle and Rabie, 1994:618). Various factors must also be taken into consideration in the development of such a policy, such as the population at risk, public perception of risk, exposure pathways, transport pathways, protection measures, variations in space and time, etc.

2.3.2.2 "De Minimis" Risk

Should it be assumed that the "acceptable risk" is achieved at a level where the concentration of a substance is equal to Q in Figure 3, another possibility arises: that the concentration of the substance is equal to Q_1. This concentration would result in a level of exposure that is lower than that at "acceptable risk". Regarding substances present at Q_1 levels, Asante-Duah (1993:32) states that "these are levels assumed to be so insignificant (as not) to be of any social concern or to justify use of management resources to control them, compared with other beneficial uses of the limited resources available in practice". Some substances may be released into the environment or consumed by humans at a level which does not cause a harmful effect or **any** known impact, and such release is then termed "***de minimis***". The term "*de minimis*" describes the introduction of potentially harmful substances into the environment, at a **level** which does not constitute an unacceptable environmental risk under **any** circumstances. For example, in very low levels, nitrate is essential for the functioning of many ecosystems, and fluoride is needed for the development of teeth. Risk is "*de minimis*" if the incremental risk posed by an activity is sufficiently small that there is no incentive to modify the activity (Whipple, 1987 in Asante-Duah, 1993:32).

It will therefore be allowable for an industry to introduce low levels of certain substances into the environment, without establishing control over such releases. Simply stated, the *de minimis* principle assumes that extremely low risks are trivial and need not be controlled, and a *de minimis* risk level would represent a cut-off point below which a regulatory agency could simply ignore alleged problems or hazards (Asante-Duah, 1993:32). According to Rowe (1983, in Asante-Duah, 1993:32), it is possible to use *de minimis* levels below which such an agency need not be concerned in the process of establishing risk levels. In contrast to the political determining of acceptable risk, a *de minimis* risk should be established on the basis of scientific principles. There are several approaches to deriving *de minimis* risk levels, but the point at which they are fixed must be scientifically justifiable on the basis of the expected socio-economic, environmental and health impacts. In this regard, when considering a *de minimis* risk level, the possibility of multiple *de minimis* exposures with a consequential aggregate risk being higher than acceptable risk should also not be overlooked.

In some instances, the level of exposure at the point where risk is deemed acceptable is set at the *de minimis* level, but this is not necessarily either accurate or justifiable. As stated above, the acceptable risk is often determined as a result of a political decision, and although it would be ideal to set the level of exposure at acceptable risk at the *de minimis* level, it must be recognised that this would not necessarily be truly sustainable. While the level of exposure at acceptable risk should ensure maintenance of public and environmental health and safety, the level representing a *de minimis* risk should define the threshold for regulatory involvement (Asante-Duah, 1993:32). Finally, it must be noted that the concept of *de minimis* is essentially a threshold concept, in that it postulates a threshold below which there will be indifference to changes in the level of risk. Examples of *de minimis* or threshold levels are NOEL or "No Observed Effects Level", or, when data with which to identify a NOEL are lacking, a LOEL or "Lowest Observed Effects Level". Also, an ADI or "Acceptable Daily Intake", determined from continuous daily exposure of humans to a substance without observed effects, is considered a *de minimis* level.

2.3.2.3 ENVIRONMENTAL STANDARDS

A key tool for environmental management is that of environmental standards (Soliman & Ward, 1994:139). The setting of standards was one of the earliest means of controlling pollution, but many standards are set to protect only a subset of the environment. Since our knowledge of the environment is continually expanding, the environmental manager, irrespective of acting in a regulatory or private sector capacity, must continue to assess whether meeting a set standard adequately protects the environment as a whole (Farmer, 1997:9). Standards are developed in different ways, the simplest being that of determining thresholds for significant effects by examining available information, and using these numbers as standards, for example the special phosphate standard set for effluents in certain South African catchments (RSA, 1984). Another method would be to derive standards from well-defined toxicity test procedures, where the concentrations of substances that cause a given proportion of a test population to die (e.g. LC_{50} – lethal concentration causing 50% mortality) are used to derive standards. Sometimes, because of uncertainty and due to the fact that the given population may not be particularly sensitive to the specific substance, a safety factor is incorporated into the results obtained, e.g. dividing the LC_{50} result by 10 or 100. In this case the standard set cannot be considered to be a "threshold" for any known effect, it is a "safe" or "acceptable" level (Farmer, 1997:10). However, for many substances there are no thresholds for effect, or organisms react differently to similar levels of pollution. In such cases, a risk assessment is undertaken and a value is derived, using a combination of the above-mentioned methods. Standards could be deduced from exposure at acceptable risk, but should rather be set at the exposure levels of *de minimis* risks, since standards give an indication only of the potential for pollution, and are normally used to activate regulatory intervention.

2.3.2.4 POLLUTION RISK LEVELS

When a substance is being released into the environment at the concentration represented by Q_2 in Figure 3, or where a situation exists that causes exposure at Q_2, such release or situation will result in a high or unacceptable damage cost to society, and therefore constitutes a risk that is not acceptable. The resulting hazard level will have a harmful effect, and such release can be considered as being hazardous and causing pollution. The release of substances at levels where the risk posed by them is deemed acceptable can be considered to be "sustainable use" of the resource. Where contaminants are present at levels causing the risk to be unacceptable, however, the term "pollution" applies. According to Keller (1992:264), from a public health or ecological point of view, a pollutant is any biological, chemical, or physical substance or circumstance in which identifiable excess is known to cause harm to other organisms. Therefore, an excessive amount of heavy metals, certain radioactive isotopes, phosphorous, nitrogen, sodium and other useful elements (or even necessary elements, such as trace elements), as well as certain pathogenic bacteria and viruses, are all potential pollutants. The discussion above implies that for all substances, there will be a certain level where disposal or discharge can be deemed acceptable, and where this level of acceptability is for each substance will depend on the inherent properties of the particular substance. Above this level of acceptability, a disposal or discharge will pose a risk of harm. Levels of acceptability thus differ, and this can be illustrated as follows:

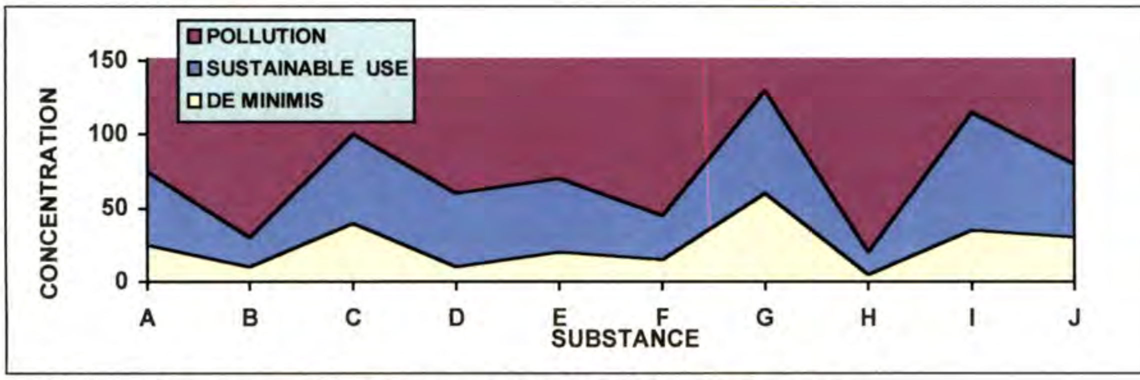

Figure 4: Pollution, sustainable use, and threshold (*de minimis*) Levels

These levels of pollution and sustainable use and threshold do not depend solely on the characteristics of the waste itself, but also on the circumstances of disposal or discharge. A fairly "inert" waste could be considered harmful when disposed in a particularly sensitive environment.

In conclusion then, **"pollution"** is always harmful in some way or to some component of society, and can be defined (Blowers, 1994:72; Farmer, 1997:3 and s 1 of the NWA) as:

> The direct or indirect introduction, as a result of human activity, of substances or energy into the environment which may cause hazards to human health and/or harm to living resources and ecological systems, damage to property, structures or amenities, or interference with legitimate uses or quality of the environment.

In order to determine how pollution is to be prevented from the perspective of the principles of sustainability, the internationally-accepted hierarchy of options for waste management is explored in the next section.

2.4 HIERARCHY OF OPTIONS FOR SUSTAINABLE WASTE MANAGEMENT

Waste management has been defined as any activity or intervention which directly, or indirectly, affects the production, handling and ultimate disposal of waste. Blowers (1994:71) observes that sustainability can only be achieved if energy and resources are conserved by reducing waste and if resources are protected by the prevention and control of pollution. Waste management can therefore be regarded as the process of making decisions with regard to the most sustainable manner in which to deal with a specific type of waste, and starts with the **prevention** of the initial production of the waste. Waste management therefore entails both **minimising** the amount of waste produced and **managing** the disposal or discharge of the residue waste stream, and is based on three key objectives, namely:

- To reduce the amount of waste produced;
- To make the best possible use of the waste that is produced; and
- To implement management practices, in accordance with the cradle to grave principle, that minimise harm to human health and risk of immediate and future environmental pollution before, during and after the waste is disposed of or discharged.

To achieve these objectives, different waste management options are ranked into a hierarchy, which broadly indicates their suitability for achieving sustainability. The Integrated Waste Management (IWM) approach maintains that waste management must be planned in advance (DWAF, 1998b:1-2), since the nature, composition and quantities of waste can be predicted at each point in the product life cycle (**cradle to grave principle**). The process of safe and responsible waste management that is based on this idea of advance planning, consists of the implementation of the five steps illustrated in Figure 5 below (adapted from DWAF, 1998b:1-2), in their hierarchical order of progression:

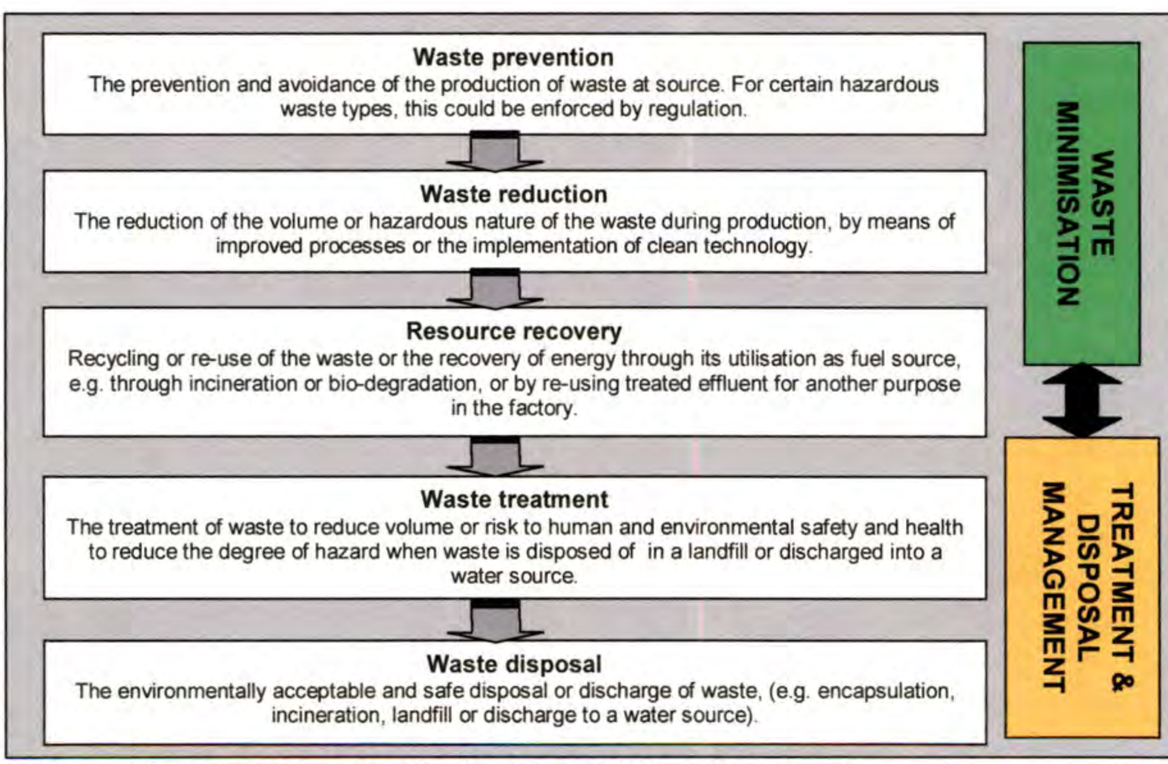

Figure 5: Hierarchy of steps for achieving Integrated Waste Management

The definition of waste as contained in the NWA makes this internationally-accepted hierarchy of option for waste management applicable to all types of waste, irrespective of the composition, origin, or percentage of moisture content. The first three steps represented above, i.e. waste prevention, waste reduction and resource recovery, refer to steps taken (preferably) at source, i.e.

by industry in order to avoid, as far as possible, the generation of waste. The last two steps refer to measures taken to reduce risks posed by the waste before, during, and after disposal or discharge. This means that waste management can be divided into two broad categories, namely waste management aimed at minimisation, and waste management aimed at ultimate disposal or discharge. Law (1996:102) emphasises this distinction, and goes even further by stating that "waste minimisation is not waste management", thereby stressing the difference between approaches to the management of waste at source and the management of final disposal or discharge. In waste minimisation, the focus is on the source of the waste (Law, 1996:102), and actions taken to reduce the amount of waste produced can include the prevention of waste generation, resource recovery and utilisation, and waste treatment in order to facilitate such recovery and utilisation.

Although controversial, the disposal of waste on land or into a water resource can be done in a manner that is sustainable (Westlake, 1997:454), once options for waste minimisation have been exhausted. Nevertheless, disposal should only be considered for specific waste types suitable for the method (Keller, 1992:293), and where waste from multiple sources is disposed of in the same area, the different types of waste should be compatible (Asante-Duah, 1993:5). In order to ensure sustainability, a sound knowledge is required regarding the potential impacts of such disposal, and decision-making procedures, site selection criteria and management practices must be implemented to prevent negative impacts from occurring. The management of waste for disposal or discharge may include storage, separation of certain waste streams to reduce their volume, treatment to reduce quantity and risk, and final disposal or discharge of the residue waste stream. Hawkins (1996:12) states that the choice of waste management techniques for any particular waste stream will be guided by the principle of best practical means. When waste management is approached from an integrated environmental management perspective, it is implicit that the **BPEO** must be implemented when decisions regarding these activities and interventions are made.

2.4.1 WASTE MINIMISATION

Waste minimisation strategies have their foundation in the **precautionary principle** and are inseparably linked to the management of waste for disposal, since the only sure way of preventing potentially hazardous waste from entering the environment is through the implementation of strategies aimed at minimising the waste at source (Law, 1996:104). Source reduction has the objective of reducing the amount of waste that is produced by a manufacturing or other process, and includes the prevention of the generation of the waste as well as the minimisation of the amount of waste that is produced. Recycling and resource recovery aim to recover the usable components or materials contained in the waste before it is disposed of or discharged (Cecelia, 1985 in Keller, 1992:298).

Waste minimisation strategies entail more than minimising the amount of waste going to a landfill or being discharged into a river, and include minimising the source of the waste (e.g. by implementing more effective process technologies, and reducing consumption of raw products). This entails changes in industrial processes, and is often referred to as "cleaner production technology". Since waste usually represents the unused part of non-renewable resources, recovery, re-use and recycling must be the prime objectives in a waste management strategy (Blowers, 1994:71). Law (1996:104) highlights the following reasons why waste minimisation should take primacy over other forms of pollution control:

- It is the only certain way of limiting waste entering the environment;
- It is crucial to the prevention of future pollution problems;
- It is the most cost effective option for industry as well as government

Bredenhann, Wates and Joubert (1996:49) observed that current waste management practices in South Africa do not include waste minimisation initiatives, but allow uninhibited waste production and primarily focus on the treatment and disposal of waste. This is mainly due to ignorance on the part of industry, as well as shortcomings in the current legislative and regulatory framework.

The attitude of South African industry is, however, starting to change, since waste management becomes more costly as environmental regulations become more stringent about disposal and discharge (Law, 1996:99). After the publication of the Minimum Requirements, which set higher standards than previously for waste disposal by landfill, costs for the disposal of hazardous waste increased dramatically (Timm, 1994:540). It is therefore in the best interests of business to implement waste minimisation strategies, as illustrated for the petrochemical industry by Smit (1996:459). Bredenhann *et al.* (1996:50) also emphasise the importance of waste minimisation strategies, and state that it is vitally important to develop incentives to sustain the ongoing evolution of cleaner production technology. A regulatory assessment procedure that compels industry to assess different waste streams separately, and that alerts generators to potential options for minimisation of these different streams, will therefore effectively reduce the risk of waste entering the environment.

Robinson (1996:21) supports this view, stating that the main priority for more sustainable waste management must be the reduction of waste generation to the minimum, and must include the priority of minimising or even eliminating potentially hazardous components of waste. This must also include strategies for re-use, recycling and recovery, and initiatives such as "energy from waste", incineration, etc. One waste management initiative that can be considered as both "minimisation" and "disposal", is the so-called thermal treatment method.

2.4.1.1 THERMAL TREATMENT METHODS

Although thermal treatment methods, such as incineration, cement kilns and pyrolysis, are not, strictly speaking direct waste minimisation methods, they are important treatment methods used to reduce the volume of combustible high risk waste by 50 to 90% by burning at high temperatures (Schneider, 1970, in Keller, 1992:286) to non-combustible residues of ash, gas and water. The chief application of thermal treatment methods is the destruction of waste posing an acute risk to human health and safety (high risk wastes: see Figure 8, page 31), such as bio-hazardous, infectious, medical, and carcinogenic organic waste (DWAF, 1998b:9-5). Their use for the management of urban domestic waste can be questioned, since it has been shown by Young (1991, in Keller, 1992:286) that an investment of 8 billion US dollars in the construction of incinerators in the United States of America will address 25% of that country's waste, while the same investment in recycling and composting facilities would handle 75% of the waste. The high cost of thermal treatment methods is due to the need for considerable atmospheric pollution prevention and control equipment, since the combustion of wastes containing sulphur and chlorine can lead to the generation of considerable quantities of acid gases, such as sulphur-dioxide and dioxins. These gases must be scrubbed from the gas stream prior to release into the atmosphere. It has, however, been argued (Robinson, 1996:22) that incineration can be sustainable if well managed and controlled, and can be a source of energy recovered from waste.

However, Robinson (1996:23) also states that it is a fact that waste minimisation incentives such as energy from waste, etc., will necessitate a continued role for discharge or disposal, since some form of residue will always remain which must be accommodated in the environment in some manner.

2.4.2 WASTE TREATMENT, DISPOSAL AND DISCHARGE MANAGEMENT

According to Westlake (1997: 460) and Robinson (1996:24), sustainable treatment, disposal or discharge of waste is an essential part of any integrated waste management strategy, without which effective waste management would not be possible. Law (1996:103) agrees, stating that waste management by means of treatment and disposal or discharge has its place in the sustainable management of waste, and although a last resort, will continue to be the BPEO for some waste types well into and beyond the next century. When the three waste minimisation steps in the hierarchy of waste management are effectively implemented by waste generators, the volume and hazardous nature of waste that will have to be managed through the fourth and fifth steps will be much less than in the current situation. However, the principles of sustainability apply as much (if not more) to the waste management options at the bottom of the hierarchy as to those at the top, since the risks posed are greater when waste eventually reaches the environment.

The "**cradle to grave**" principle implies that there is "No away", and that nothing can be disposed of and forgotten. This idea is founded in the basic scientific rule that matter cannot be created or destroyed. When waste is "disposed of", it is in fact merely being "stored" in a facility that is designed to mitigate against the risks posed by such "storage", and when waste is "discharged" into a water resource, it is not gone forever; it is merely transported to a different location, where it may settle out or be removed so that the water can be re-used. This principle therefore places a duty on the waste generator, who must ensure that his waste is firstly **treated** to reduce risks associated with public safety and acute human health, before **disposal** or **discharge** in an responsible manner that will reduce the chronic human and environmental health risks.

Treatment and disposal management measures are closely intertwined, since treatment measures are aimed at achieving sustainable disposal or discharge by reducing the risks associated with these actions. The two main components that determine the sustainability of the treatment, disposal or discharge management option are:

- the intrinsic potential hazards associated with the waste itself and the pathways by means of which this hazard can be realised, as well as
- the characteristics or vulnerability of the receiving environment, including the presence or absence of the different pathways.

In most instances, the waste may require some form of **treatment** to reduce its intrinsic hazards, and the BPEO for the correct treatment technology must therefore be determined, so that it can be applied to the waste prior to disposal on land or discharge into a water resource. In other instances, management measures are taken not to reduce the risk posed by the waste through treatment, but to reduce the risk by enhancing the protection of the environment. Sustainable final disposal and discharge management requires that the waste materials be safely assimilated into the surrounding environment, whether or not risk-reduction measures aimed at the source have been implemented to minimise the impact on the environment (Westlake, 1997:453). It must be noted that the implementation of these treatment and disposal management measures can also, in some instances, lead to waste minimisation. Furthermore, it can be argued that the discharge of effluent into a water resource is, in essence, “recycling”, especially in a water-deficient country like South Africa. Waste with a high moisture content must therefore first be purified through one or more of the risk-reduction measures aimed at the source to a level that is acceptable, before the treated water may be returned to the water resource in a manner that is sustainable. Therefore, even if the waste is treated to reduce the associated risk to a certain level, **disposal** or **discharge** cannot take place indiscriminately, and it is of the utmost importance also to optimise management options for the final disposal or discharge of waste from the perspective of sustainability.

Since risk-reduction measures aimed at reducing the hazard posed by the waste and/or enhancing the protection of the environment are costly, the combined consideration of the two components listed above will determine whether an action offer a sustainable level of protection to the receiving water environment. This implies that the risks posed by the waste itself, and also the ability of the receiving environment to deal with these risks or the effects of its exposure to these risks must first be considered before a decision regarding the correct treatment, disposal or discharge management option is made. The assessment procedure aimed at determining the BPEO for the most effective risk-reduction measures should therefore indicate these risks before the ultimate disposal or discharge of the waste in a suitable environment.

This, in essence, constitutes the research question. The two assessment mechanisms currently used to determine whether a disposal or discharge is indeed sustainable, or whether it causes pollution, will be described and evaluated in chapter 4 to determine whether an assessment conducted under them will lead to the implementation of the BPEO for treatment, disposal or discharge.

The fifth step in the hierarchy of options for waste management does not apply only to the management measures taken at facilities for the disposal of waste that have been constructed or selected for effluent discharge, it is also relevant to historical disposal practices and "contaminated" sites. Several authors (Asante-Duah, 1993:1; Grasso, 1993:1 and others) regard the management of such historical disposal sites and activities, specifically the remediation of sites where unacceptable environmental risks are present, as an important environmental priority because of their high and unassessed potential for harm to the public and the environment, as well as because of the potential financial liabilities for the parties responsible for these sites.

A regulatory procedure that can prioritise contaminated sites and polluting activities on the basis of the degree of risk or hazard they pose will assist greatly in the implementation of cost-effective remediation measures.

2.5 SUMMARY

In the preceding discussion, the concepts of sustainability and pollution have been investigated in terms of the principles of environmental management. From this investigation, and according to international thinking, it is evident that waste must be assessed from a risk-based perspective aiming to deduce the BPEO for managing waste-generating and disposal activities within a strategic hierarchy of options for waste management, which moves from waste minimisation to ultimately sustainable disposal or discharge management. To determine the BPEO for risk-reduction measures, the potential impacts of the disposal or discharge action must be assessed in an integrated manner, which traverses the boundaries of traditional scientific fields of study.

These impacts will be explored in more detail in the next chapter, along with the legal controls aimed at regulating waste disposal and discharge actions and international thinking regarding assessment of and decision-making regarding such impacts.

CHAPTER 3: IMPACTS, LEGISLATION, ASSESSMENT AND DECISION-MAKING

3.1 INTRODUCTION

As discussed in the previous chapter, waste disposal or discharge into the environment is an integral part of sustainable waste management, provided that such disposal or discharge is managed in such a manner that the environmental risk is acceptable (Westlake, 1997:453). When determining options for the sustainable management of waste disposal or discharge, two aspects are of particular significance, namely:

- the source of an impact (the waste itself, and the various degrees of hazard it poses), and
- the receiving environment, which includes natural systems and populations at risk, both human and non-human.

The interaction of these aspects is especially important when dealing with the risk of water pollution, since the many different sources of pollution will have different impacts on the different components of the resource (Keller, 1992:264). The presence or absence of pathways by means of which these risks can be realised should also be taken into account. Potential impacts must be taken into consideration when deciding on risk-reduction measures such as treatment (for the sustainable disposal of waste both into a water resource or onto land), selection of suitable disposal media or locations and selection and design of barrier systems, as well as in selection of mitigatory measures for the remediation of contaminated sites. Weale (1992:5) observes that the most obvious feature of potential pollution problems is that they concern resources, which are public goods, and the risk of pollution often arises from otherwise legitimate activities within society. The consequence is that the control of pollution is typically a regulatory policy since society must be protected from pollution by government action. The advent of a democratic South Africa has brought about the promulgation of the Constitution of the Republic of South Africa Act 108 of 1996. Section 24 of the Constitution has caused a paradigm shift towards a new environmental policy for South Africa, and new statutory requirements, which are based on the internationally-accepted principles of sustainability discussed in chapter 2, have been promulgated to give effect to this change. One of the first principles for action of the Brundtland Commission is that: "decisions should be based on the best possible scientific information and analysis of risks" (DoE, 1998:1). In the light of these new frames of reference, it becomes evident that a risk-based approach must be followed for regulatory assessment and decision-making regarding the disposal or discharge of waste on land or in the water resource. In this chapter, the impacts of waste disposal and discharge on the environment are investigated, the legal provisions that guide decision-making when dealing with these impacts are discussed, and the principles and components of risk analysis (i.e. risk assessment and risk management) are introduced.

3.2 THE SOURCE: PATHWAYS AND IMPACTS

Environmental pollution is the result of the presence or release of hazardous materials or substances into the environment (Asante-Duah, 1996:2). Hawkins (1996:9) states that all substances and materials are potentially hazardous. Particular circumstances dictate whether such materials are actually harmful or hazardous, with the risk being the likelihood of actual occurrence of harm. **Hazardous or harmful waste** is therefore any substance that, when released into the environment at a level that causes or could cause **pollution**, which has been defined as an unacceptable risk of harm to human safety, human health, or the environment (Asante-Duah, 1993:2; Blackman, 1996:36; Noble, 1992: Vol. 4, 4-5 and others). The identification of the types of potentially hazardous materials is therefore important in the investigation of the potential risks associated with the release of such materials into the environment (Asante-Duah, 1996:2). Several factors determine the hazard posed by the presence of substances in the environment, such as physical form and composition, quantity (volume), reactivity (flammability, explosion), biological and ecological effects (toxicity and concentration), mobility (potential to be transported in the various environmental media), persistence (accumulation), indirect health effects (pathogens and vectors), as well as pathways of transport and exposure (Asante-Duah, 1996:9 and Keller, 1992:270). The two factors that have the greaatest influence on the realisation of the hazard, are the pathway and the response, and these aspects are discussed in more detail below.

3.2.1 EXPOSURE AND TRANSPORT PATHWAYS

The first factor that influences the potential harmful effect of a substance on a receptor is the pathway by means of which the exposure occurs (see Figure 2, page 14) as well as the degree of exposure of people or other potential recipients (Keller, 1992:270). It is, however, not only the exposure pathway that is important, but also the transport pathway that must be taken into consideration. In order to illustrate these complexities, a simplified conceptual diagram of potential transport pathways of chemicals through an ecosystem is given in Figure 6 (from Asante-Duah, 1993:123).

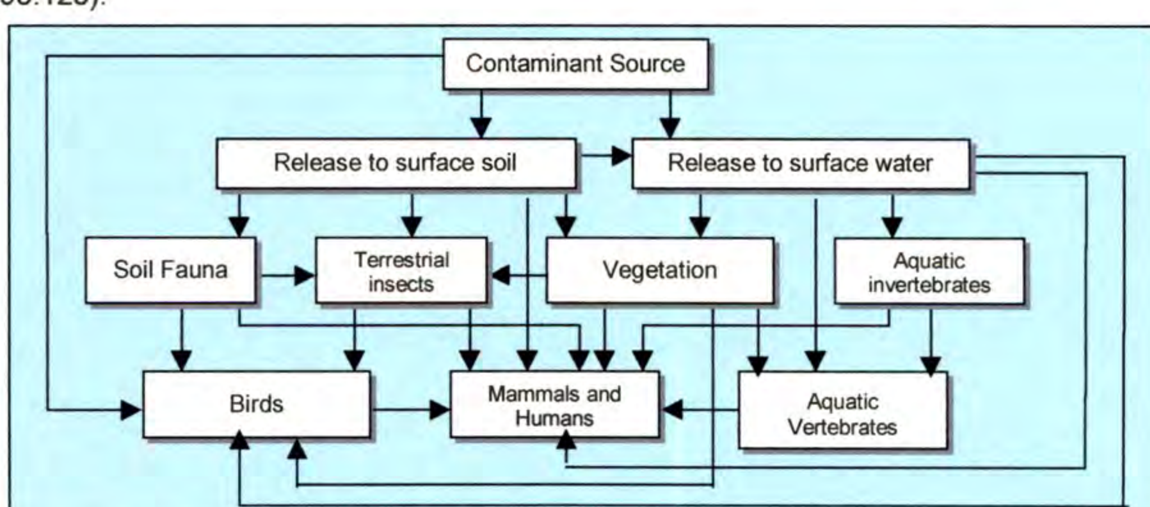

Figure 6: Simplified diagram of transport pathways in an ecosystem

Duffus and Worth (1996:4) state that substances can only cause harm if they reach parts of persons or organisms that are sensitive to them, in a sufficiently high concentration and for a sufficient length of time. The major routes of exposure are through the skin (absorption), the lungs (inhalation), or the gastrointestinal tract (ingestion). Some substances will have no effect if ingested, but could have detrimental effects on health if inhaled (e.g. asbestos, dusts and some gases).

3.2.2 DOSE – RESPONSE RELATIONSHIPS

Small quantities of some components (such as trace metals) are essential for the functioning of organisms and systems, but may cause death if taken in excessive quantities. In the case of essential compounds, there is a gradual transition from deficiency to effectiveness to fatal toxicity. Other compounds, which are not essential for functioning, may have no effect at low concentrations, but may also lead to death at high levels (Duffus and Worth, 1996:20). The concept that is of importance is "dose" – the concentration to which the receptor is exposed to over time. The relationship between the dose of the substance and the response of the receptor is generally non-linear and S-shaped. A simplified example of the "dose-response" relationship for fluoride is illustrated below:

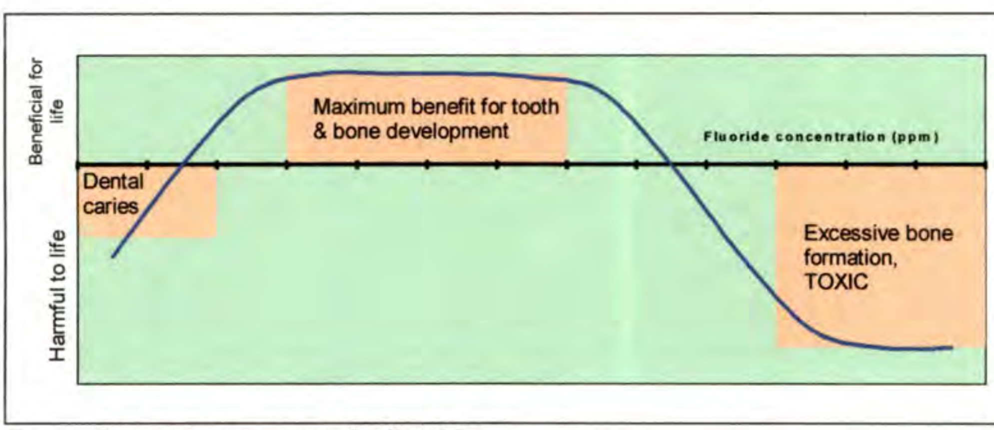

Figure 7: Dose-response curve for fluoride

Various other factors also influence the realisation of a hazard. In some instances, a material may be considered a pollutant for a particular segment of society, although it is not harmful to other segments of the population, e.g. excessive sodium as a salt is not generally harmful, but it is to some people on diets restricting salt intake for medical reasons (Keller, 1992:264).

3.2.3 CATEGORISATION OF WASTES

From the discussion above, it is clear that there are varying degrees of hazards associated with different waste streams, and Asante-Duah (1993:4) stresses the importance of recognising the fact that there are management advantages to ranking wastes according to the level of hazard they present. Such a categorisation is depicted in Figure 8 below (Asante-Duah, 1993:5), which shows that potential hazards can be grouped into four distinct groups, in terms of the seriousness of their potential effects and for the purpose of implementing risk-reduction measures.

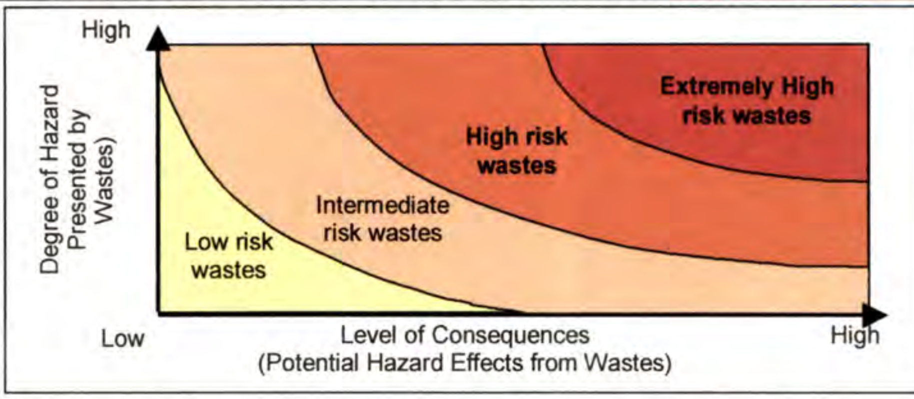

Figure 8: Conceptual categorisation scheme for hazardous waste classification

❶ Extremely high risk: Potentially acute hazard to safety of people;

❷ High Risk: Potentially acute (or chronic) hazard to health of people;

❸ Intermediate Risk: Potentially chronic hazard to health of people or environmental systems;

❹ Low risk: Potential hazard to environmental systems, and/or property, and/or nuisance.

3.2.4 RISK-REDUCTION MEASURES AIMED AT THE SOURCE

Treatment technologies aimed at reducing the risks posed by the waste will not be discussed in detail, but could include chemical, physical and biological treatment technologies and methods, such as chemical stabilisation, incineration, filtration, cooling, settlement, chlorination, desalination, electrodialysis, flocculation, flotation, etc. (DWAF, 1998b:A7-1-3). For the extremely high and high risk wastes, the level of exposure is easily determined, since these are wastes known to contain significant quantities of constituents that are highly reactive, unstable, flammable or explosive (causing a safety risk), or toxic, infectious, mobile, persistent, carcinogenic and/or bio-accumulative (causing an acute health hazard) (Asante-Duah, 1993:3). There should be strict directives regarding how to deal with these wastes through pre-treatment, since they are of priority concern in terms of their impact on human health and safety, and no level of exposure to them can be considered acceptable. Examples include explosives, chlorinated solvents, bio-hazardous medical wastes, poly-chlorinated biphenol (PCB) wastes, dioxin-based wastes etc, and they are normally treated with thermal treatment methods or special disposal techniques, such as encapsulation, to reduce the risks associated with them. Metal hydroxide sludges, sewerage sludges and high salt content brines are examples of high and intermediate-risk waste, which should preferably be disposed of in a landfill site that offers high protection to the environment, provided that the waste is pre-treated to ensure that the hazardous components are in relatively insoluble physical form. Unfortunately such waste is sometimes discarded in an uncontrolled manner by discharge into a water resource or disposal on land in open dumps, domestic waste sites or "evaporation dams". Low risk waste primarily includes high volume, low hazard waste with some putrescent waste. Examples include industrial effluents, dry industrial waste, domestic waste, and domestic waste water, for which the cut-off point between hazardous and non-hazardous is less clear-cut (Batstone, 1989 in Asante-Duah, 1993:4). For these kinds of waste, depending on their composition and the environmental circumstances, acceptable management could include either discharge into a river or disposal in a low- or medium protection waste disposal site (see section 3.3.3), with or without pre-treatment.

3.3 THE RECEIVING ENVIRONMENT: IMPACTS AND PATHWAYS

As discussed previously, potential risk to the environment depends not only on the properties of the waste, but is also a function of the presence or absence of pathways, the vulnerability of the environment, and the safeguards implemented to reduce the potential realisation of risk. Keller (1992:243) observes that the recognition of the integrated nature of the environment, especially the hydrological cycle and the interrelationships between surface water, ground water and atmospheric water, evolved only in the past fifty years. The management and protection of water resources is a complex issue that is becoming more difficult as the demand for water increases (Keller, 1992:263). Luna Leopold emphasises the need for a new philosophy of water management, based on the integration of sciences (geology, chemistry, etc.) with traditional economic, social and political factors (in Keller, 1992:263). Therefore, irrespective of whether waste or water containing waste is disposed of on land, vented into the atmosphere, or discharged into a water resource, the resulting impact on the water resource must be evaluated from an integrated perspective to determine the BPEO for reducing the risk associated with the disposal or discharge of the waste. In this section, the various components of the water resource that can be influenced by waste disposal or discharge are briefly introduced, followed by a discussion of pollution problems experienced as a result of these activities, and of how the risk of such problems can be prevented or reduced.

3.3.1 COMPONENTS OF THE WATER RESOURCE

The global water cycle is indivisible, and involves the flow or movement of water between different "storage" compartments. In its simplest form, it involves the movement of water from the oceans and freshwater bodies to the atmosphere, its precipitation from the atmosphere onto the ocean, land, or freshwater bodies, and its return to either the oceans and freshwater bodies, as surface runoff or subsurface flow, or to the atmosphere as evaporation. The interrelationship between some of these components of the water resource can be illustrated as follows (Keller, 1992:251):

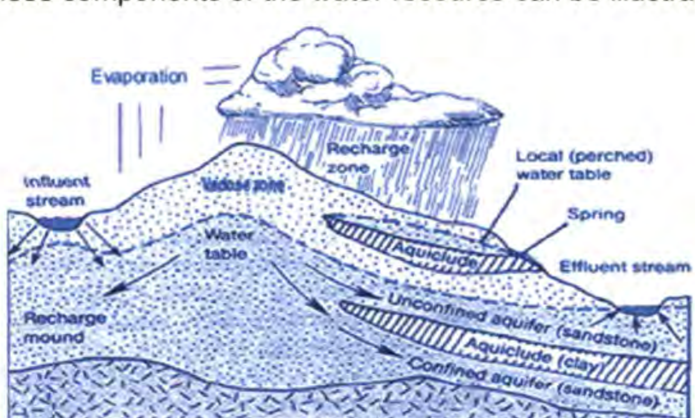

Figure 9: Interrelationships between atmospheric, surface and ground water

In order to develop an understanding of these interrelationships when considering the impact of waste disposal or discharge on this environment, input from the fields of geology, chemistry, microbiology, engineering and toxicology are required, but the following basic concepts will facilitate some understanding of the relationships illustrated in Figure 9. The major source of ground water is precipitation that infiltrates the surface and moves through the **vadose zone**, an underground portion of land that is seldom saturated with water. The vadose zone has special significance because potential pollutants on the surface must percolate through it before they enter the saturated zone.The upper surface of the saturated zone is known as the **water table** (Keller, 1992:249). An **aquifer** is defined (RSA, 1998a:14) as "a geological formation which has structures or textures that hold water or permit appreciable water movement through them", and a zone of earth material that, although capable of holding water, will not transmit it fast enough for it to be pumped from a borehole, is known as an **aquitard** (Keller, 1992:250). In terms of the surface water component, the interrelationship between streams and ground water must also be highlighted. **Effluent streams** tend to be perennial, since ground water seeps into them during the dry season, maintaining stream flow (the term "effluent stream" in this context does not refer to water containing waste, but to streams fed by ground water flow). **Influent streams** are found above the ground water table, flow in direct response to precipitation, and may be intermittent or ephemeral. From the perspective of this study, influent streams are important because water pollution in a stream may move downward through the stream bed and eventually pollute the ground water found below, particularly if the river bed is dry, or fed only by waste water. When the ground water has been polluted, it may present a pollution problem to the users of water in an effluent stream.

3.3.2 IMPACTS OF POLLUTION ON THE ENVIRONMENT RESULTING FROM WASTE DISPOSAL AND DISCHARGE

Waste disposal on land can result in soil, water and air pollution, although the most severe impact is normally on the water resource (Asante-Duah, 1996:154). Waste discharge usually impacts mainly on the water resource into which it is discharged. Table 4 below provides an illustrative set of examples of the sort of problems which can be, and are, experienced when waste is disposed of or discharged in a manner that may constitute pollution of the water resource (Weale, 1992:4).

Table 4: Pollution problems resulting from the impact of human activities on the water resource

Water Pollution problem	*Human activity*	*Main pollutants*	*Expected effects*
Introduction and Dispersal of chemicals and wastes in the: → **freshwater environment** → **marine environment** → **soil and ground water environment**	▪ Domestic waste disposal ▪ Concentrated habitation and untreated sewage disposal ▪ Industrial waste discharge ▪ Mining waste discharge ▪ Fossil fuel burning for power, heating and transport ▪ Farming	Nitrates Phosphates Acid rain Sewage Heavy metals Pesticides Carcinogens Organics	Human deaths Human Diseases Species loss Resource depletion Resource loss Economic losses to: • tourism • industry • society Water supply contamination

Water pollution is the degradation of water quality as measured by biological, physical or chemical criteria, and this degradation is generally judged in terms of the intended use of the water, its departure from the norm, its effects on public health, or ecological impacts (Keller, 1992:264). If the intended use is, for example, recreation and eco-tourism, any deviation from natural background levels (norm) may well be deemed pollution. Pollutants can enter the water environment from both point and non-point sources. **Point sources** are discreet and defined, such as pipes of canals emptying into (mainly) surface water bodies from municipal or industrial sites. In general (Keller, 1992:268), the control of point sources before discharge, through on-site treatment, is easier than the control of non-point sources. **Non-point sources** are diffuse and intermittent, influenced by factors such as land use, climate, hydrology, vegetation and geology, and difficult to control. Non-point sources result from the intentional or unintentional disposal or discharge of waste on land, and include urban and industrial runoff from streets or fields, which may contain all types of pollutants, from heavy metals to sediment. Rural sources of non-point pollution are generally associated with mining, agriculture or forestry (Keller, 1992:268). Non-point sources can impact on both surface and ground water components of the water resource. It is furthermore recognised (Keller, 1992:267) that the sediment content of such waste streams has not yet been adequately addressed, and could well be, in volume, the greatest pollution problem related to surface water bodies. Such removal obviously has a cost implication, and the higher the level of impurity, the more expensive the treatment of the water for re-use.

Of particular importance in the consideration of pollution problems in any component of the water resource, are the residence times and reservoir sizes of water in the various parts of the cycle. Water in rivers has a residence time of about two weeks, whereas water in ground water bodies has a residence time of hundreds to thousands of years. Therefore, a solitary pollution incident (such as a spill from a rural sewerage works) will have a short-lived impact because the water will soon leave the river environment (provided that the incident does not involve the adsorption of pollutants onto sediment on the river bed, which would result in a much longer residence time). Pollution problems are more likely to result from chronic processes which discharge pollutants directly into rivers or onto land over an extended period of time (Keller, 1992:245). Due to the fact that the residence time of ground water is so long, natural removal of pollutants from ground water is a slow process, and abatement is extremely difficult and costly. The protection of ground water resources is an environmental problem of particular concern because so many people in this country derive their domestic water supplies from ground water, and also because it maintains the base flow of most perennial streams (Keller, 1992:255) which means many South African rivers.
Reservoir size of surface water bodies is also of particular importance when determining assimilative capacity, as well as for ground water when determining potential importance for use.
Apart from these factors relating to pollution of the water resource, there are additional factors to consider when waste is disposed of on land.

3.3.2.1 ADDITIONAL IMPACTS OF LAND-BASED DISPOSAL OF WASTE

The major environmental concern associated with waste disposal on land involves the control of liquid and airborne emissions (e.g. leachate, seepage, biogas) (Cossu, 1996:584), which are generated as a result of the decomposition of the waste following such disposal. These emissions can result from contaminated areas, as well as various types of land-based disposal methods (Keller, 1992:298), such as surface impoundments (e.g. the impoundments containing phosphorous waste near Meyerton); landfill sites; composting and land application; deep well disposal (e.g. for radio-active waste near Vaalputs in the Northern Cape Province); slimes dams, rock dumps and sand dumps at mines; the storage of materials not regarded as waste (such as material stockpiles at industries) and open waste dumps.

If waste, irrespective of whether it contains moisture or not, is disposed of on land, it will inevitably come into contact with water, whether it is rain or ground water moving laterally through the waste. In some cases, high liquid content waste percolates down from the surface. When waste comes into contact with water, **leachate** – an obnoxious, mineralised liquid with high organic content capable of transporting bacterial pollutants – is produced (Keller, 1992:286). Figure 10 shows the high volume of leachate produced at a South African waste disposal site as a result of the historical disposal of high volumes of liquid waste:

Figure 10: Large volume of leachate produced at a waste disposal site

Freeze and Cherry (1979 in Fourie, 1994:199), Parsons (1996:400) and others state that the production of leachate is one of the most significant hazards associated with land-based disposal of waste or storage of materials, and can cause severe ground and surface water pollution. The volume, nature and strength of leachate produced at a particular site depends on the amount of water that infiltrates or moves through the waste (which depends on the composition of the waste – liquid content and chemical characteristics – and climatic conditions), as well as the length of time that the infiltrated water is in contact with the waste. When waste containing water is disposed of on land in an uncontrolled manner by means of irrigation (e.g. of sewerage sludge) or surface impoundments (e.g. evaporation facilities or slimes dams), the infiltration and seepage into the environment of the polluted waste water itself will also pose a risk to both the surface water and ground water resource. Seepage has been recognised as a pollution threat or many years (Fourie, 1994:199), and excavations have uncovered bitumen lined seepage drains in Mesopotamia dated circa 3200BC (Kays, 1977 in Fourie, 1994:199).

Another potential hazard associated with waste disposal on land is the production of atmospheric emissions, such as **biogas, volatile compounds, and dust. Biogas** is the natural product of anaerobic decomposition of biodegradable refuse (Letcher, 1994 in Coetzer, 1994:407), and typically contains about 50% methane with the complement mainly carbon-dioxide. The uncontrolled escape and migration of methane can result in explosion. Biogas can, however, be utilised as a source of energy for vehicle propulsion and other applications (Coetzer, 1994:414). Other emissions that can cause harm include volatile organic compounds (which are carcinogenic), acid gasses, and dust, the PM10 fraction of which can also cause cancer.

Land-based waste disposal and management scenarios can be divided into:

- Waste disposal sites that are poorly selected, unlined, of substandard design or poorly managed, where all types of waste had been or are being disposed of and that cause pollution; and
- Well-selected, well-designed and well-managed land-based waste treatment and disposal facilities (WTDF's) used as secure storage areas for low risk hazardous waste and for the sanitary disposal of domestic waste in a sustainable manner.

This implies that pollution problems can be prevented by implementing risk-reduction measures as well as by investigating methods of protecting the environment.

3.3.3 RISK-REDUCTION AND ENVIRONMENTAL PROTECTION MEASURES

As discussed in section 3.2.4, high-risk waste should not be disposed of or discharged into the environment unless some form of treatment has been applied to it, and in a sustainable waste management system, it will be mostly intermediate and low-risk waste (including the residue of treated high-risk waste) that has to be accommodated in the environment in some manner. However, as explained in the preceding discussion, such introduction can still cause potential problems, and additional risk-reduction and environmental protection measures must be implemented. Although the water resource is indivisible, these measures can differ depending on the source of the waste, as well as the component of the environment that they are designed to protect. The different conditions that may influence the risk when waste is disposed of or discharged, include the following:

- For discharge into a water resource: assimilative capacity, existing or potential use, sensitivity of the resource components, etc.; and
- For disposal on land: site selection, geological characteristics, engineering design, operation, etc.

Some risk-reduction and environmental protection measures are discussed below.

3.3.3.1 RISK-REDUCTION MEASURES FOR WASTE DISCHARGE INTO A WATER RESOURCE

In this section, the focus is on the disposal of the (purified, treated or untreated) waste stream into a resource. Such discharge may be sustainable, depending on the circumstances, since pollution of surface water occurs only when too much of an undesirable or harmful substance is discharged into a resource, so that the natural ability of the ecosystem to utilise or remove the undesirable material, or convert it to a harmless form, is exceeded (Keller, 1992:267). This corresponds with the concept of carrying capacity discussed previously, and is also acknowledged by Principle 15 of the National Water Policy (DWAF, 1997a:35,36), which states, "Water quality and quantity are interdependent and shall be managed in an **integrated** manner, which is consistent with broader environmental management principles". The use of the surface water environment for the transport and management of unwanted waste products has long been recognised as a non-consumptive use of the water resource, and does not necessarily cause pollution of the environment. In earlier times, surface water resources (rivers and oceans) were used for the disposal of all types of waste, ranging from domestic garbage (high solids content) to assorted wastes with high liquid contents (e.g. paper mill waste). During the first century of the industrial revolution, the volume of waste produced was small, and the approach of "dilute and disperse" was considered to be adequate waste management, because of the large available assimilative capacity. Keller (1992:283) observes that factories were located near rivers because the water provided easy transport for materials by boat (if it was a navigable river), easy communication possibilities, sufficient water for processing and cooling, and **easy disposal of waste into the river**. As populations and industrial and urban areas expanded, and the need for water for consumptive human use grew, the realisation that the approach of "dilute and disperse" was not only no longer adequate, but was, in fact, detrimental, started to dawn on humanity. Owing to the outbreak of diseases of epidemical proportions (e.g. typhus), as well as the strong visual impact of waste with a high solid content, the disposal of these types of waste directly into a water resource was the first to be prohibited (Keller, 1992: 303). A new approach, known as "concentrate and contain" was implemented to facilitate risk-reduction. This means that industrial effluents containing waste are nowadays treated to reduce the waste components by removing them to a level where the treated liquid component can be returned to the water resource, which is in line with the principle of recycling and re-use. The disposal of the **concentrated** fraction containing the "removed" waste components will then be managed by means of secure land-based disposal (**containment**). Both the pre-treatment, as discussed in sections 2.4.2 and 3.2.4, and containment, as discussed in the next section, have huge cost implications, and the level of optimum exposure will therefore determine when the purification of the waste water is sustainable. Ragas and Leuven (1999:185) observes that two complementary approaches can be followed in establishing emission limits for industrial discharges, namely a technology approach (BPEO) and a water quality requirement of the user approach. They conclude (1999:191) that a combined technology and water quality based approach should be followed when establishing emission limits for discharges since it is in line with the pollution prevention and carrying capacity principles. The following figure can be used to illustrate how the carrying capacity of a resource should be managed, from a risk-reduction perspective, for the point source discharge of water containing waste into a water resource (adapted from Pedersen *et al.*, 1995:10 and Keller, 1992:265):

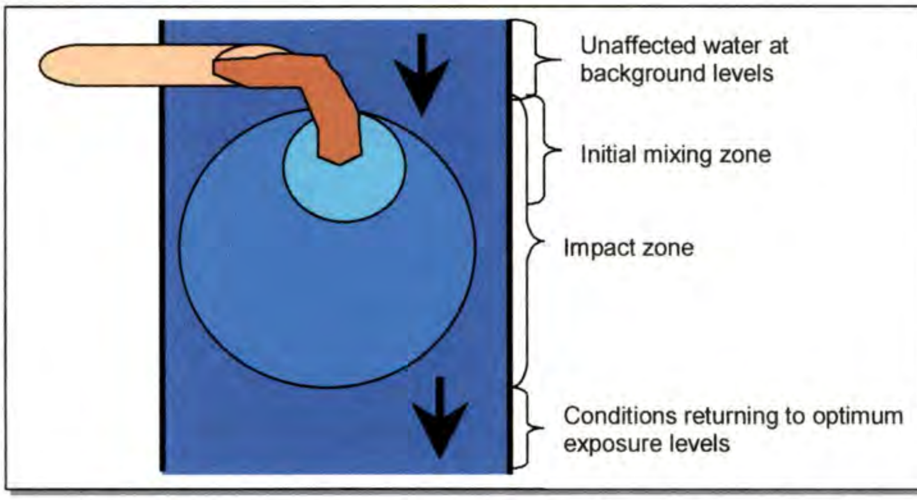

Figure 11: Schematic representation of zones influenced by waste water discharge

According to Pedersen, Damborg and Kristensen (1995:9), for discharge to be considered sustainable, acute toxic effects in any potential recipient should not be allowed to occur within the impact zone after initial dilution in the initial mixing zone. When evaluating the acceptability of a waste discharge into a water resource, information on the individual chemical components, as well as physico-chemical properties, degradability, bio-accumulativity and toxicity is required. However, since knowledge regarding the chemical content of waste water and the effects of these chemicals is often limited, and in order to examine the cumulative effect of the components of the waste water, it is sometimes also necessary to assess the whole effluent in terms of its toxicological properties (Pedersen *et al.*, 1995:10). Furthermore, these authors state that it is assumed that any potential chronic effects should be kept within the smallest possible impact zone after the discharge point. They conclude that there is a need for methods to establish both short-term maximum exposure levels and long-term average exposure levels for recipients. Based on the above, it is evident that the following environmental circumstances will determine whether the discharge of waste water into a water resource will constitute a sustainable use, or pollution, of the resource:

- The intended or actual use of the resource;
- The effects of the discharge on the recipients (human and ecological) using the resource using the resource;
- The carrying capacity of the resource;
- The hydrological characteristics of the resource;
- The baseline or background quality of the resource; and
- The treatment applied to the waste water before discharge.

Ragas and Leuven (1999:191) support this, stating that water quality objectives should not only be specified as concentration levels, but should include a spatial and temporal specification, i.e. maximum mixing zone dimensions and maximum allowable excursion frequency and duration. Therefore, the determination of no-effect (*de minimis* or threshold) levels, and the calculation of potential concentrations of substances in waste water are key parameters for the evaluation of whether a waste water discharge may have a detrimental impact, as well as of the ability of the receiving environment to return conditions to what they were before the impact occurred, in order to ensure that an action is sustainable.

3.3.3.2 RISK-REDUCTION MEASURES FOR SUSTAINABLE LAND-BASED WASTE DISPOSAL

Waste disposal on land can be considered environmentally sustainable if it is properly carried out (Robinson, 1996:22 and Westlake, 1997:454). Proper site selection, design and operation can prevent both short- and long-term impacts from occurring. The following factors can contribute to a reduction of the risk when waste is disposed of on land:

- Appropriate site selection, aimed at addressing both short and long-term impacts;
- Secure site design, which is aimed mainly at minimising long-term impacts;
- Sanitary site management and standards of operation, which are aimed mainly at the management of short-term impacts and hazards; and
- Measurement of the occurrence of failures that could lead to the realisation of risks (monitoring).

The concept of **sequential land use** (Keller, 1992:284) is acknowledged in the definition of landfill as: "the engineered deposit of waste onto and into land in such a way that pollution or harm to the environment is prevented, and, through restoration, land is provided which may be used for another purpose" (ISWA, 1992 in Westlake, 1997:453). This definition encompasses all methods and practices of land-based waste disposal, not only domestic waste disposal in a conventional landfill. This means, for example, that a clay quarry can be used for waste disposal, and after rehabilitation, the land can be turned into a sports field, park or botanical garden. Because of continued settlement and gas generation, the construction of buildings and dwellings on conventional waste disposal sites is generally avoided (Fourie, 1994:203). This risk-based definition recognises that because national and regional geohydrology, topography, weather, flora and fauna, as well as disposal requirements and day to day situations, can vary, appropriate technology and techniques for one site may not be appropriate for another, and the risks associated with different sites may be different. The key element of sustainable waste disposal on land is that these differences, and differences in the specific natures of the hazards associated with the types of waste that can be handled, are recognised within an environmental risk assessment process, so that site-specific risks can be measured and used to support appropriate site selection, design, management and control (Westlake, 1997:454).

According to Westlake (1997:456), risk- and hazard-reduction appear to be the most easily-achievable means of ensuring sustainable landfill, since control of the pathway element is feasible, and may be achieved by the use of appropriate site location and optimal liner design.; If these requirements are fulfilled, the site will not be regarded as posing a risk, but rather as offering protection to the environment. Depending on the optimisation of the four factors listed above, such protection could be regarded as high, moderate or low, categories which suggest guidelines for the types of waste that can safely be accepted at a site.

3.3.3.2.1 Site selection considerations

When a site is selected from a sustainability perspective, the focus should be on areas with a large vadose zone, where clay and silt soils of low hydraulic conductivity are present, and a large buffer zone, where a potential hazard will not result from exposure pathways to populations at risk. According to Keller (1992:287) and DWAF (1998c:4-6 – 4-7), factors influencing feasibility in the selection of a sustainable landfill can be divided into:

- environmental considerations (e.g. topographic relief, wind directions, precipitation, type and depth of soil and rock, distance from and use of water resources);
- economic considerations (e.g. availability of land, distance from populations served, economics of scale, accessibility, availability of cover material); and
- social considerations (e.g. distance from populations at risk, visual impact).

Asante-Duah (1993:159) observes that typical issues for decision regarding waste disposal site selection can be addressed by the use of risk assessment concepts and techniques. The presence of an adequate buffer zone between the site and potential populations at risk, is the most important factor that must be taken into consideration during site selection, since this is the only barrier system mitigating against airborne pollution pathways, which cannot be addressed by means of engineering measures.

3.3.3.2.2 Secure site design

Keller (1992:293) states that the basic idea of engineered design for sustainable waste disposal on land is to confine the waste to as small an area as possible, and to intercept, contain and control leachate or seepage, since these measures will prevent pollution. Cossu (1996:584) observes that for this reason, an effective barrier system between the environment and the area of waste disposal must be provided, which can include a compacted clay layer or series of layers, supplemented with synthetic layers. The principle of engineering a barrier system between the site and the environment, as well as implementing a leachate or seepage management system (consisting of detection, collection and storage facilities), is not applicable only to conventional waste disposal sites, but also to other types of land-based disposal of waste or storage of materials. For example, slimes dams constructed for mining waste are designed also with systems aimed at collecting seepage, such as toe-ponds and return water dams. The design will depend on the type of waste accepted at the site (McPhail, 1994:187), the potential for leachate generation and the consequences of failure. McPhail further contends that the most objective method of determining appropriate design measures is that of a risk based approach. According to Westlake (1997:456), the principle of containment offers the most sustainable option for waste disposal on land, although Keller (1992:293) recognises that the containment barrier can ultimately fail since time scales beyond that of a single generation are involved in potential ground water pollution. According to Druyts and Legge (1996:91), the design of the site must also make provision for storm water management, and leachate control or holding facilities must also be designed on the basis of the containment principle.

3.3.3.2.3 Sanitary site management and operation

According to Baldwin (1994), operational factors are extremely important, as there are many examples of sites that have been selected well and engineered to the highest standards, and yet, owing to poor operation, have become a considerable environmental risk. Sustainable waste disposal and sanitary **landfill** is defined by the American Society of Civil Engineers as a method of disposing of waste on land without creating nuisances or hazards to public heath or safety (DWAF, 1998c:G-8 and Keller, 1992:286). Managing a site properly has long-term benefits, such as isolating the waste from the environment, and thus avoiding the ingress of surface water into the waste, which could cause the generation of leachate and landfill gas (Keller, 1992:286).

An operational factor that influences leachate generation is the **acceptance** of waste with a high **liquid or moisture content**. It has been shown that the moisture content of domestic waste is approximately 30% (DWAF, 1998c:A10-1,2) by dry mass. This means that in certain areas, with high rainfall supplementing this moisture content, high volumes of leachate will be generated at sites accepting only domestic waste. The disposal of wastes with high moisture content from industrial origin along with domestic refuse is known as **co-disposal** (DWAF, 1998c:G-2). In some instances, it may be more environmentally acceptable to dispose of low-risk waste (e.g. waste water sludges containing inorganic components and heavy metals), in properly designed and operated sanitary landfills (Novella et. al, 1994:93) than by means of other land application techniques. If the ratio of low moisture-content waste to high moisture-content waste, or co-disposal ratio, exceeds a certain limit, the volume and nature of the leachate generated will no longer be manageable. Recognised by the UK Hazardous Waste Inspectorate as a potential BPEO for the management of certain high moisture content industrial waste (Baldwin, 1998:2), the co-disposal ratio is an aspect of site management which must be controlled in terms of climatic conditions, waste type and the moisture content thereof, amongst other factors. The protection offered by the site will change into a risk to the environment when this ratio is not well managed, since the co-disposal of certain industrial waste with domestic waste can lead to significant solubilisation of organic ligands in leachate (Boswell and Baldwin, 1998:441), and can lead to stability problems which can place the design of the site in jeopardy.

The management of **biogas** or other potential atmospheric pollutants, such as respirable dust, as well as the nuisance of odours, can also give an indication of whether a site is operated in a sustainable manner, or whether it is causing pollution (Burger, 1994:142). Since objection to odours is the main cause of the NIMBY phenomenon ("Not In My Back Yard") (Murphy, 1994:171), the importance of this aspect should not be underestimated and should be addressed in the operation of the site. Proper covering and compaction, as well as the prevention of the disposal of substances with high potential for generating odours, should address the generation of odours, while the management of biogas can be addressed by means of passive or active gas extraction.

Another factor that will determine the influence of the operation of a site is the presence and management of **waste reclaimers** or "scavengers". Diaz (1994:47) observes that scavenging is carried out at most landfills in the developing world, and in poorer countries provides an income to many families. It is usually carried out in a disorganised manner, which places the lives of the reclaimers at risk and which has a negative impact on the operation of the site, with resulting legal liabilities for the operator or owner of the site. When it is organised and managed in a more formal system, the reclaimers are no longer "scavengers" contributing to the problems of waste management, but are entrepreneurs who assist in the sustainable management of waste.

Land-based waste disposal activities can be regarded as offering high, intermediate or low protection to the environment, or as posing a high, intermediate or low risk to the environment, depending on the degree of selection, design or operation.

3.3.4 REMEDIATION OF POLLUTING ACTIONS AND CONTAMINATED AREAS

Open dumps, historical waste sites and contaminated areas, unmanaged storage or disposal areas, surface impoundments, and sites of substandard design and management are, although not acceptable waste management options, still in use in many parts of the world, including South Africa. The best-known international example of problems associated with uncontrolled waste disposal is the Love Canal site in Niagra Falls (Keller, 1992:290), which caused severe health impairment to local residents, and in South Africa, the Thor Chemicals issue is still an unresolved matter. Many facilities such as these are unlined and "rely" only on natural geology to prevent the migration of leachate and seepage contaminants (Folkes, 1982 in Fourie, 1994:199). In recent years, following the publication of the Minimum Requirements documents that outline acceptable waste management practices for South Africa, a few of these sites have been upgraded (e.g. New England Road in Pietermaritzburg) or closed (e.g. Umlazi IV near Durban), but many are still in use today.

These sites represent all types of disposal practices, from domestic waste dumps and sewerage sludge disposal areas, to hazardous waste impoundments and some mine slimes dams, and their associated hazards result mainly from poor siting and design and/or poorer management and operation. Most surface impoundments are badly designed, and are especially prone to seepage, resulting in pollution of surface and ground water (Keller, 1992:294). Evaporation from some types of waste stored in these impoundments can sometimes cause air pollution problems, and other types of waste stored in impoundments can pose a risk of fire or explosion. **Composting, land application**, land spreading or land farming (Keller, 1992:293) have limited application in a country that depends heavily on ground water for its potable water supply, and are not effective treatment or disposal methods for waste containing inorganic substances such as salts or heavy metals (Huddlestone, 1979, in Keller, 1992:293). According to Keller (1992:294,295), **deep well disposal** of industrial waste is also not a quick and easy waste management solution since, even when geological conditions are favourable, natural restrictions include the limited number of suitable sites and the limited space available within these sites. Also, several problems are associated with the disposal of liquid waste in deep wells, such as leakage from the wells, which can cause pollution problems to usable aquifers, and even an increase in seismic activity and the occurrence of earthquakes.

In most cases, these types of dumps are located wherever land is or was available, and some continue to be operated without regard to safety, human health, and aesthetics (Keller, 1992:286). There are many South African examples, for instance the Bisasar Road Landfill site operated by the Durban Metropolitan Council, which is situated within 20 metres of a formal residential area while managing up to 3 000 tons of waste per day. Depending on location, local conditions, siting, etc., these types of waste disposal areas could be regarded as having a high, moderate or low risk in terms of their impact on the environment, which may be short- and/or long-term. Short-term impacts include nuisance problems such as noise, pests, odours, air pollution (dust, burning piles of waste), windblown litter, etc. These are sometimes unsightly and can create health hazards, but they may be addressed by proper operation and should cease with the closure of the site. Long-term impacts include problems such as pollution of ground and surface water, as well as uncontrolled landfill gas generation. These problems are generally associated with poor site selection, design and operation, and may persist long after the site has been closed. It is of the utmost importance that these activities be identified and prioritised in order to prevent a situation that can lead to disaster. According to Asante-Duah (1997:14), the establishment of national regulatory requirements is a major step in developing effective waste and contaminated site management programmes.

3.4 NEW STATUTORY REQUIREMENTS

At the beginning of the twentieth century South Africa, like many countries, had no legislation in place to combat, let alone to identify, pollution, and the prevailing water quality probably did not warrant such legislation (Fuggle & Rabie, 1994:470). Before 1956, the Irrigation and Conservation of Waters Act 8 of 1912 protected the water rights of farmers along rivers and concentrated on the construction of works to benefit irrigation. No statutory measures were in place to control the purification and disposal of effluent or waste. The first legislation with a pollution-control component was the Public Health Act of 1919, which prohibited the discharge of sewage into streams (DWA, 1986:8.7). Pollution was therefore not regulated by any water legislation. In anticipation of water shortages and recognition of the deteriorating quality of water in the country, the Water Act 54 of 1956, codified a large body of pre- and post-Union legislation, and s21 of this Act controlled the discharge of effluent as administered by DWAF. In 1989, DWAF also became responsible for the administration of s20 of the Environment Conservation Act 73 of 1989, which deals with permitting of waste disposal sites. It was in terms of these two sections that the two approaches, under evaluation in chapter 4, were developed as decision-making tools.

The legal situation changed markedly with the advent of a democratic South Africa, which lead to the promulgation of the Constitution, which lays the foundation for a more just and equitable South African society. A number of the fundamental rights that are guaranteed by the Bill of Rights contained in the Constitution, which is the cornerstone of the democracy in South Africa, are significant to the environment and therefore fall within the ambit of this study. Section 24 of the Bill of Rights (RSA, 1996:10,11) enshrines the principles of pollution prevention and the concepts of sustainable development and sustainable use discussed in the previous Chapter, stating that:

> *Everyone has the right –*
> *(a) to an environment that is **not harmful** to their health or wellbeing; and*
> *(b) to have the environment **protected**, for the benefit of present and future generations, through **reasonable legislative** and other measures that –*
> *(i) **prevent pollution** and ecological degradation;*
> *(ii) **promote conservation**; and*
> *(iii) secure ecologically **sustainable development and use of natural resources** while promoting justifiable economic and social development.*

This is a shift away from away from the old approach, which pitted environmental concerns against economic and developmental aspirations, by requiring that they be integrated. Section 27, which deals with access to water, and ss32 and 33, which guarantee access to information and just administrative action, complement this right. The National Environmental Management Act (Act 107 of 1998) (NEMA) contains general provisions regarding environmental management, and the National Water Act, 1998 (Act 36 of 1998) (NWA) was formulated to give legislative effect to ss24 and 27 of the Constitution (Stein, 1999:7), insofar as the water resource is concerned.

Before the promulgation of the NWA, assented to by the President of South Africa on 20 August 1998 (RSA, 1998a), the legislative framework within which the discharge or disposal of waste was regulated was regarded as patchy and uncoordinated and not always or necessarily based on sustainability principles, as observed by Peckham (1994:88), Fuggle and Rabie (1994:99) and Loots (1994:23). The NWA replaces the previous Water Act 54 of 1956, and repeals more than 100 other Acts dealing with water. Following a process of wide consultation and an extensive review of all water laws in South Africa, drawing from the experience of other drought-ridden countries, and based on 28 Principles contained in the "Fundamental Principles and Objectives for a New Water Law in South Africa", which were approved by Cabinet in November 1996 (DWAF, 1997a:3), the "White Paper on a National Water Policy for South Africa" (DWAF, 1997a) was published. The Fundamental Principles support the objectives of sustainability and equity which underpin the entire NWA as central guiding principles in the protection, use, development, conservation, management and control of our water resources (Stein, 1999:7). The following issues are considered important in relation to decision-making regarding the disposal or discharge of waste in the environment (some other concepts that are introduced or defined in the Act are included in the Glossary of Terms listed at the end of this document):

1. The scientific indivisibility of the water resource is recognised, and the Minister of Water Affairs, as the ***public trustee*** of this resource, will be accountable for ensuring that decisions do not adversely affect the integrity of the resource, but are made in a **just and equitable** manner which promotes environmental values.
2. The concept of "***the Reserve***", which comprises that quantity and quality of water required to satisfy basic human needs and to protect aquatic ecosystems, in order to ensure ecologically-sustainable water development and use (Stein, 1999:11), is introduced. This concept is based on s24 and 27 of the Constitution (Stein, 1999:11) as formulated in **Principle 9:** "The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be **reserved** so that the human use of water does not individually or cumulatively compromise the long-term sustainability of aquatic and associated ecosystems" (DWAF, 1997a:35).
3. In the NWA, use of water is no longer limited to consumptive use such as abstraction of water, but non-consumptive **use of the water resource** is also recognised in that the NWA provides for tiered regulatory control over an extended list of possible water uses identified in s21 (RSA, 1998a:36), which includes, amongst other uses:
   - ⇒ controlled activities– activities which impact detrimentally on a water resource (activities identified in s37(1) or declared as controlled activities under s38(1)) such as (s21(e)):
     - ☞ irrigation of land with waste or water containing waste which is generated through an industrial activity or a waterwork; or
     - ☞ intentional recharge of an aquifer with any waste or water containing waste;
   - ⇒ discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit (s21(f));
   - ⇒ disposing of waste (or water which contains waste) in a manner which may detrimentally impact on a water resource (s21(g)); and
   - ⇒ disposing in **any** manner of water which contains waste from, or has been heated in, any industrial or power generation process (s21(h)).

   The NWA recognises water as a valuable commodity, since all authorised use of water will now be charged for through a pricing strategy for water use charges in terms of s56(2).
4. After providing for the Reserve and international obligations, the basis for granting authorisation to use the water available in an area will be the achievement of beneficial use in

the public interest (also referred to as "**optimum use**", i.e. use which achieves the most desirable combination of social, economic and environmental objectives) (DWAF, 1997a:17), irrespective of whether such use is consumptive or non-consumptive. According to s27(c) (RSA, 1998a:44), all water uses, except the Schedule 1 uses, will be authorised only if they are efficient and **beneficial to the public interest,** and will be subject to a system of allocation that promotes use which is optimal for the achievement of equitable and sustainable economic and social development.

5. To achieve effective **resource protection**, two distinct but integrated sets of measures are required, namely ***resource-directed*** and ***source-directed*** measures (DWAF, 1997a:19). Resource-directed measures must set clear objectives for the desired level of protection for each component of the resource through a resource classification system. Source-directed measures aim to control the source of potential impact on the water resource so that the resource protection objectives are achieved.
6. On the basis of the constitutional obligation to **protect** the environment, stringent **pollution prevention** measures and the "**polluter pays**" principle are incorporated into the NWA. According to **Principle 16:** "Water quality management options shall include the use of economic incentives and penalties to reduce pollution; and the possibility of irretrievable environmental degradation as a result of **pollution shall be prevented**". In fulfilment of this principle "waste discharge charges", as intended under s 56(5) of the NWA can be set for uses that are not beneficial and in the public interest.

The NEMA was promulgated on 27 November 1998, and came into operation in January 1999. The aim of the NEMA is "to provide for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state; and to provide for matters connected therewith" (RSA, 1998b:2). It can be described as South Africa's "primary" or "parent" environmental statute and guides decision-making in all South African legislation concerned with the environment (Stein, 1999:2). It is important to note that the BPEO is defined in the NEMA as "the option that provides the most benefit or causes the least damage to the environment as a whole, at **a cost acceptable** to society, in the long term as well as the short term". NEMA reiterates the provisions of s24 of the Constitution, contains the internationally-accepted principles of sustainability (RSA, 1998b:10, 12, 14) (see section 2.2.1, page 10), applies throughout the country, and must be complied with in all actions of all organs of state. It is therefore a legal requirement that these principles must be taken into consideration as a general framework with reference to which all decisions that may affect the environment must be made. The NEMA also outlines the need for an approach that differentiates between pollution and sustainable use, and states that a **risk-averse and cautious approach**, which takes into account the limits of current knowledge about the consequences of decisions and actions, must be used in decision-making. Furthermore, the need for intergovernmental co-ordination and **harmonisation** of policies, legislation, and actions relating to the environment, is emphasised.

3.5 RISK HARMONISATION: THE INTEGRATION OF DECISION-MAKING AND ASSESSMENT APPROACHES

As stated in the problem statement of this study, the mere fact that two different approaches currently exist for determining the risks posed to the water resource implies the need for an integrated harmonised assessment and decision-making framework in order to achieve sustainability as legislated in new statutory requirements. Agenda 21 (DEAT, 1998a:40, 43) states that the assessment of impacts and risks of wastes for human health and the environment must be facilitated by the establishment of appropriate procedures, methodologies, criteria and/or effluent-related guidelines and standards, and that risk assessment should be strengthened internationally for this purpose. It must, however, be emphasised that risk assessment is not risk management, but that the objective of risk assessment is to provide vital scientific input into the management process, especially regarding the appropriate management option to be taken.

Typical management decisions that could be made on the basis of input from a prior risk assessment of a specific problem, can include the following aspects of sustainable waste management as discussed in chapter 2 (Asante-Duah (1993:161) and Robinson (1996:25)):

- Deciding how much of a chemical a company may discharge into a river;
- Deciding which substances may be disposed of at a particular waste management facility;
- Setting standard levels for discharge, storage or transport of hazardous materials;
- Determining allowable levels of contamination in drinking water;
- Establishing site selection, design, engineering and operation protocols for the management of waste disposal facilities;
- Prioritisation of contaminated sites or existing pollution problems for remedial action;
- Development of clean-up criteria and guidelines for contaminated sites; and
- Evaluation of corrective measures and selection of remedial alternatives.

On the basis of the legal requirements discussed above, it is evident that the assessment and management of risk to the water resource resulting from the disposal or discharge of waste should be conducted in an integrated and harmonised manner. It is therefore necessary to investigate the components of current international approaches to risk analysis in order to determine whether the existing South African approaches addresses all relevant aspects. The integration of risk assessment and risk management into a harmonised framework is known as risk analysis, as illustrated in Figure 12 (overleaf) (adaptation of Asante-Duah, 1993:162; Kamrin, 1997:140; United Kingdom Department of Environment Guidelines for Risk Assessment ("UK Guidelines"), DoE, 1998:39 and Fuggle & Rabie, 1994:596).

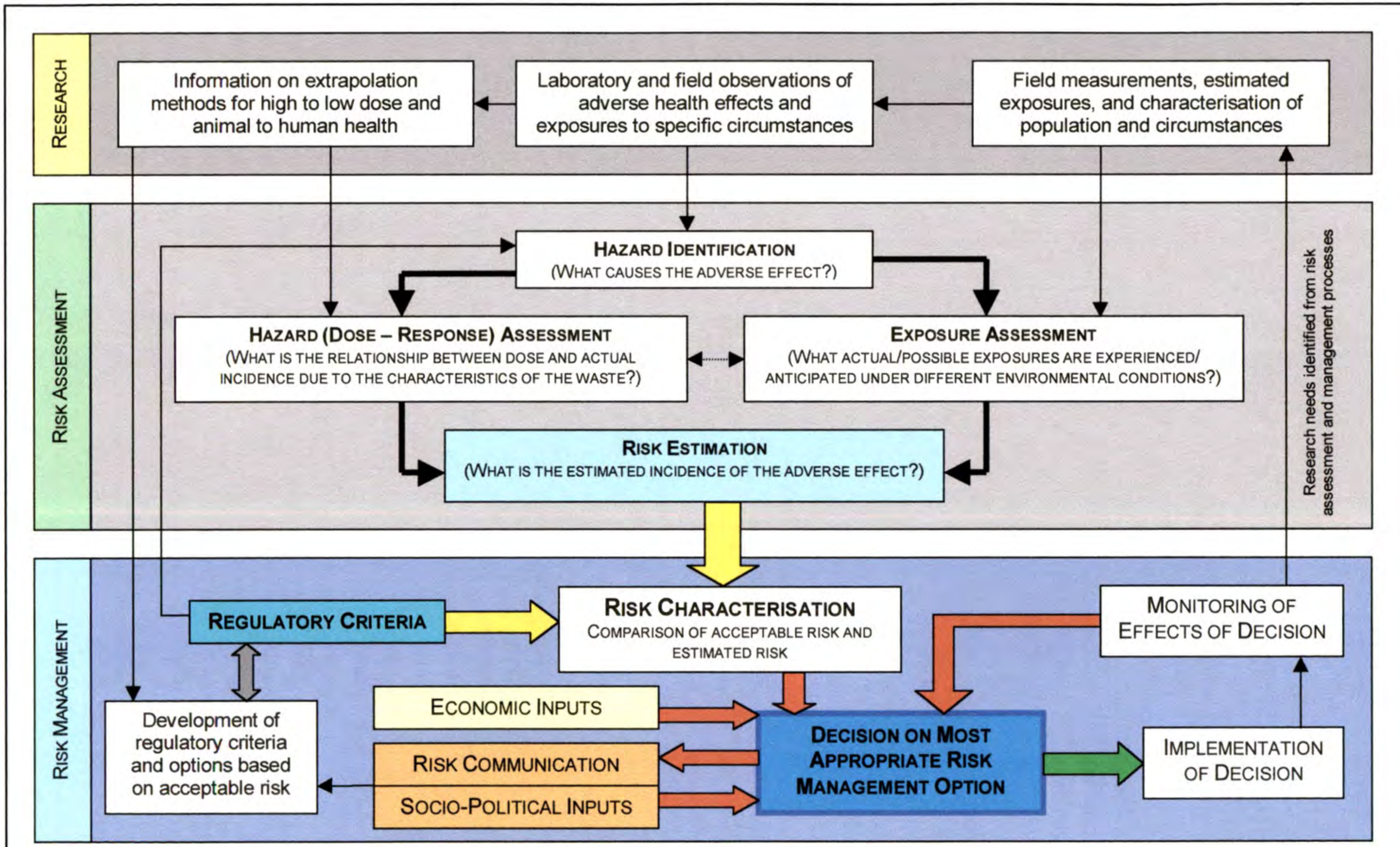

Figure 12: Harmonised Risk Analysis Framework

3.5.1 RISK ASSESSMENT

Risk assessment is the structured gathering of available information about risks, and the forming of a judgement regarding such risks (DoE, 1998:3). In a generic sense, it is defined (Asante-Duah, 1996:117) as a systematic process of making estimates of all the significant risk factors that prevail over an entire range of exposure scenarios and/or failure modes associated with some hazard situation(s). Agenda 21 (DEAT: 1998b:40) specifies that international risk assessment should be strengthened to eliminate unacceptable or unreasonable risks, and the UK Government guideline is that a risk assessment approach should be used to determine sustainable environmental management options. It must be noted that risk assessment is not an exact science but, as observed by Hunt (1998:93), it is one of the emerging multi-disciplinary sciences where facts are uncertain, values in dispute, stakes high, costs exorbitant and decisions urgent, and can be grouped with other "post-normal" sciences like law, medicine and economics. The purpose of risk assessment is to provide, insofar as possible, a complete set of information to the manager, so that the best possible decision can be made pertaining to a potentially hazardous situation (Asante-Duah, 1996:119). The type and degree of any risk assessment depends on its intended use. According to Asante-Duah (1993:53), Fuggle & Rabie (1994: 596), Kamrin (1997) and others, the generic risk assessment process itself involves four basic steps, which are briefly discussed below, namely:

- Identification of potential hazards;
- Assessment of Hazard (or dose-response assessment);
- Assessment of Exposure of the receiving environment; and
- Estimation of risk based on a combination of the outcomes of the above assessments.

3.5.1.1 HAZARD IDENTIFICATION

Hazard identification involves identifying chemicals and other factors of concern, such as persistence, site-specific conditions etc. (Asante-Duah, 1993:61). With regard to the action of disposing or discharging waste, the UK Guidelines (DoE, 1998:17) and Farmer (1997:7) specify that the releases (in terms of physical and chemical characteristics) that could give rise to harm **as well as** the characteristics of the receiving environment and the environmental circumstances, must be identified during this stage. Hazard identification therefore entails the identification of environmental situations and waste characteristics, both of which are normally regulated by law. This may include lists of specific contaminant sources, specific chemicals of concern, particularly sensitive receiving environments or species, etc. (Asante-Duah, 1996:122).

3.5.1.2 HAZARD (DOSE – RESPONSE) ASSESSMENT

This stage involves evaluating information on potential **sources** of hazards and their toxicological or physical properties, and characterising the relationship between the dose of the contaminant administered or potentially received, and the incidence of actual adverse safety or health effects in the potentially exposed populations (Asante-Duah, 1993:91). The DoE Guidelines (1998:19) state that the identified hazard associated with the proposed releases will be assessed during this stage in terms of:

- ⇨ Potential for causing conditions unsafe for people, such as explosions, or acute adverse health effects, such as burns;
- ⇨ Carcinogenicity, teratogenicity, mutagenicity, pathogenicity, toxicity and immunotoxicity;
- ⇨ Potential of bio-accumulation and bio-concentration in plants and animals;
- ⇨ Potential for adverse effects on environmental processes, air, water and soil (e.g. liquid content); and
- ⇨ Potential for causing offence to people.

This part of the assessment therefore seeks to identify the properties of the substances that could lead to adverse effects on the environment, during all stages of the operation and under conditions of failure or accidents (Farmer, 1997:7).

3.5.1.3 EXPOSURE ASSESSMENT

An exposure assessment is conducted to estimate the magnitude of actual and/or potential exposures to chemical or physical hazards, the frequency and duration of these exposures, the nature and size of the (potential) populations at risk, and the pathways by which exposure can occur (Asante-Duah, 1996:123). Exposure assessment is receptor based (McDonald et. al. in Kamrin, 1997:136) and involves describing the nature and size of a population at risk (i.e. exposed to a substance or physical situation), and the magnitude or duration of their exposure (Asante-Duah, 1993:67). During this stage, consequences for people or components of the receiving environment that may be exposed to the risk posed by the proposed release of substances are assessed (Farmer, 1997:7). The assessment of such consequences on people or the receiving environment must also take account of the different pathways by which they might have an effect (DoE, 1998:20), e.g. direct inhalation or ingestion, absorption through the skin or ingestion through affected food or water. The **characteristics of the receiving environment** may even be such that certain hazards will not take effect (DoE, 1998:21).

3.5.1.4 RISK ESTIMATION

Risk estimation is the process of estimating the probable incidence of adverse impacts on potential receptors under various exposure conditions (Asante-Duah, 1993:102). The qualitative, semi-quantitative and/or quantitative estimation of risk involves an integration of the outcomes of the exposure- and hazard-assessments to arrive at an **estimated risk** to the exposed, or potentially exposed, population. The consequences of the realisation of a specific hazard when a substance is released into the environment are, by definition, harm or adverse effects on human health and/or certain components of the environment (DoE, 1998:23). Identifying the consequences therefore depends on combined knowledge of the hazard and the characteristics of the potential receiving environment. This knowledge may be climatic, geographical, use-based (e.g. potential water users), etc. The likelihood of equipment failure may be predictable due to past experience, but the behaviour of a pollutant in the environment may not be quantifiable (Farmer, 1997:8), and any estimation of the probability or frequency of a hazard being realised is likely to be at best semi-quantitative (DoE, 1998:26). Risk estimation therefore usually includes an explication of the uncertainties associated with the risks estimated (Asante-Duah, 1996:123). For most actions, more than one hazard will be identified (DoE, 1998:29). An estimation is therefore made of the actual and potential risks of exposure to each separate hazard, and also the possible additive effects of exposure to mixtures of chemicals or cumulative effects. The aim should be to quantify as much as possible so as to reduce uncertainties, which requires the need for judgement and the associated scope for argument or dissent. Hunt (1998:45) states that several mathematical relationships may be used to estimate risks. The UK Guideline (DoE, 1998:26) recommends that, when quantification is not possible, the probability should at least be expressed as within a certain range of order of magnitude, for a specified number or period of time, such as one in 100-year floods. Ranges will differ according to the nature of the consequence, and can be divided into "high", "medium", "low" and "negligible". In order to focus decision making, the risks to potentially exposed populations can therefore be estimated by the calculation of quotients or indices that can be used in matrices, as illustrated below:

Table 5: Matrix for Risk Estimation from consideration of magnitude and probability of consequences

	Magnitude			
Probability	*Severe*	*Moderate*	*Mild*	*Negligible*
High	High	High	Medium/low	Near zero
Medium	High	Medium	Low	Near zero
Low	High/medium	Medium/low	Low	Near zero
Negligible	High/medium/low	Medium/low	Low	Near zero

Such ranges deliberately overlap to avoid their being used as threshold values. Furthermore, in establishing these ranges, it must be absolutely clear what is to be considered, for example: the harm caused will be different if a specific type of waste is to be disposed of in a waste site located within 100 metres of a residential area, than if it is to be disposed of in one located three kilometres from the nearest residential area (Fuggle and Rabie, 1994:594). As discussed, both hazard- and exposure-assessments are at best semi-quantitative and include uncertainties on the basis of knowledge and experience. Estimation of risk is therefore no different, but can contain judgement about such uncertainties.

3.5.1.5 LEVELS OF HAZARD AND EXPOSURE ASSESSMENT

It is evident that as much available toxicological and other data as possible need to be obtained for the assessment, as well as information on the behaviour of the receiving environment (Farmer, 1997:7). Utilising the best available scientific knowledge, the steps discussed above could involve the qualitative, semi-quantitative and/or quantitative characterisation of potential adverse consequences for or impacts on humans and ecological receptors due to exposure to hazards (Asante-Duah, 1993:24). This implies that the assessment can be done in three progressive tiers of complexity, depending on the speed with which the result of the assessment is required, or the cost of the preferred option indicated by the outcome of the assessment (Day and Vargas, 1999:2):

- Regarding both the waste stream and the receiving environment, a **tier 1 assessment** will involve comparison of the most critical characteristics with a conservative set of non-value based and value-based regulatory criteria (such as threshold levels or standards based on *de minimis* risk levels), with a default list of pre-defined scenarios. Such an assessment is normally used to facilitate quick decision-making under emergency conditions, since the outcome will often be aimed at following the most cautious route of action (precautionary principle), which may not be cost effective or feasible for actions for which a longer-term solution has to be found. For such actions, more time is available to collect additional information regarding the activity for re-assessment according to tier 2 criteria.

- A **tier 2 assessment** will involve the use of site-specific data (instead of tier 1 default levels) to determine site-specific criteria based on the relevant physical and chemical characteristics of the environment and the waste. In such a case, there is no comparison to standards, but a site-specific assessment is conducted according to an assessment procedure, specified by a regulatory body, which is based on fate and transport modelling, and into which the site-specific information is fed in order to arrive at an estimated risk. Should the responsible party deem the assumptions contained in the prescribed procedure of a tier 2 assessment to be too conservative or inapplicable to his specific situation, additional information can be collected to reassess the situation on a tier 3 level.

- An expanded, quantitative site-specific assessment, based on fault tree analysis, failure logic, event trees (Hunt, 1998:45) and sophisticated statistical, fate and transport models, which includes specific input parameters such as Monte-Carlo simulations and chemical dose-response studies, can be regarded as a **tier 3 assessment**.

Risk assessments are made by everybody, consciously or intuitively, on a daily basis. For instance, safety risks are assessed when deciding whether or not to cross a busy street, or whether or not to ignore the health risks associated with smoking. They are, however, also an integral part of many scientific disciplines. Consequences on human health have been studied in depth, and it is therefore possible to quantify their magnitude and in some instances even assign a monetary value to them. The application of risk assessment to the natural environment is regarded as a novel approach, since most work on risk assessment has been restricted to effects on human health (DoE, 1998:7). Risk assessment tools are in the early stages of being applied to ecological systems (Pleus, Dunn & Rodgers, 1998:2). Therefore, for the living environment other than humans, as well as for the non-living environment, it may be necessary to adopt a **semi-quantitative approach** in order to estimate the magnitude of effects (Asante-Duah, 1996:159).

3.5.2 RISK MANAGEMENT

Risk estimation is the final step of the risk assessment process, and forms the basis of the scientific input into risk management (Asante-Duah, 1996:137), when the outcome of the risk estimation is compared during risk characterisation with the applicable **acceptable risk, optimum exposure criteria**, or standards, as set in terms of political decisions or legislative requirements.

3.5.2.1 RISK CHARACTERISATION

Once the actual or potential risk has been assessed and estimated, it can be compared to an acceptable risk, and a decision can be made with regard to the management of the risk. One key factor is to consider whether the environment is likely to be able to withstand the effects, i.e. whether sustainability is affected (DoE, 1998:30). This can be achieved by the use of a **characterised risk quotient (RCQ)** (also referred to as Hazard Quotient or Ecological Quotient), which is obtained by dividing the estimated risk value with the acceptable risk or critical parameter value (Asante-Duah, 1996:141,159), in order to express the comparison between estimated risk and acceptable risk. The RCQ is thus important in setting priorities for dealing with existing problems, since the more the estimated risk exceeds the acceptable risk level, the higher the priority of remediation or clean-up (Asante-Duah, 1993:103). Risk characterisation therefore also entails a judgement about the significance of the estimated risk. An estimated risk lower than or equal to acceptable risk implies that further reduction in the risk can only be achieved at excessive cost, and that the benefits of incurring the risk are judged to outweigh the disadvantages.

Risk characterisation is the process of determining the significance of the identified hazards and estimated risks to those concerned with or affected by the decision, and includes the study of risk perception and the trade-off between perceived risks and perceived benefits. Since different groups have different views about what constitutes an acceptable risk, risk characterisation by these different groups will produce different results. However, a final decision regarding the management of the characterised risk will usually fall to the authority responsible for making the decision, such as the relevant governmental department or regulating authority (DoE, 1998:34). If, at the end of the assessment, the risk is judged not to be low enough to be acceptable, the action should be modified to reduce the consequences, and the risk of the modified action should then be reassessed. Also, a decision may be taken to implement the BPEO, which may entail cleaner production, treatment, altered designs, additional operational controls or other risk-reduction measures that will alter the risk, such as to implement a clean-up strategy at a contaminated site. This process is known as risk management. The characterisation of a risk may also change over time, as more information about the consequences and probabilities becomes available or the available information is better understood by those concerned. A decision to alter risks restarts the risk assessment process, with the result that risk management becomes an integral part of the iterative cycle of risk assessment (DoE, 1998:38).

3.5.2.2 RISK MANAGEMENT DECISIONS

According to Farland (in Kamrin, 1997:108), risk management is based to some degree on the outcome of the risk assessment (i.e. the estimated risk), but is also heavily influenced by political, economic and social information, some of which may be scientific. Risk management can be defined as:

- The complex synthesis of analysis and judgement that uses the results of risk assessment, combined with political, economic and social information, to produce a decision about environmental action;
- Determining and accomplishing those actions that will reduce risk to the greatest degree, given any particular level of resources;
- A system which, as a whole, is designed to balance risk against risk, although individual risk management decisions may appear to be balancing risk-reduction measures against resources; and
- A system designed to identify and deal with the worst and most controllable risks as a matter of priority.

Solutions for environmental problems need to be found from a management point of view, rather than a focus only on the problems associated with environmental elements such as air, water and land (Nel, 1994:6). Farmer (1997) goes even further, stating that although many texts treat environmental management as a scientific exercise, this is only partly the case (although a necessary condition) because environmental managers must also consider social, economic and political consequences in their decision-making. All environmental management elements should be integrated across the traditional scientific boundaries. **Integration** means that all aspects of the environment become an issue for consideration whenever any decision is made, and systems and processes are developed to ensure that this happens (Winter, 1995:36). Furthermore, environmental management must be integrated with the day to day management and decision-making processes of an organisation, and should not be considered an additional activity.

This would imply that a procedural approach aimed at distinguishing between sustainable use and pollution of the environment should take input from across scientific boundaries into account (so-called Post-Normal science (Lemons, 1996:63,77)), and must provide a decision-making tool that can be used in the day to day management of the activity.

Monitoring the effects of the risk is the final step of risk management, and a decision to tolerate a risk may even be conditional on appropriate monitoring. Monitoring also provides useful information regarding the validity of assumptions made during the risk assessment, as well as information relevant to future risk assessments.

3.5.3 RISK ANALYSIS

According to Farland (in Kamrin, 1997:108), there are fundamental differences between risk assessment and risk management, but they are often confused, so that risk assessment may be perceived as the source of a risk management decision, when in fact such a decision has been based also on social concerns, public perceptions, economic issues or other non-risk related considerations. According to Asante-Duah (1993:25), the overall purpose of risk assessment is to provide as complete as possible a set of information to managers to allow for the best possible decision to be made concerning a potentially harmful situation. The decision that is made is known as risk management. The differences between the processes of risk assessment and risk management are outlined in Table 6 (adapted from Farland (in Kamrin, 1997:109)) below.

Table 6: Environmental risk: fields of analysis

	Risk Assessment	Risk Management
Actions	Identify Describe Measure	Evaluate and Judge Decide Implement
Influencing factors	Nature of effects Potency of agent Exposure Pathways Population at risk Average risk Cumulative risk	Social importance of risk *De minimis* levels Acceptable risk Decision to reduce/not reduce risk Stringency of reduction Economics Priority of concern
	Sensitive groups *Uncertainties of science* *Uncertainties of analysis*	*Legislative mandates* *Legal issues* *Risk perception*

As stated in the UK Guidelines (DoE, 1998:55), risk analysis in the context of sustainable development is still in its infancy and, as with all new developments, it is often treated with scepticism and sometimes dismissed as being too difficult. It is, however only by dealing with its difficulties that they will be overcome, especially as feedback from monitoring improves knowledge, minimises uncertainties, and obviates perceptions.

3.5.3.1 ISSUES IN RISK ANALYSIS

The two main factors to be considered are uncertainty, which influences risk assessment, and risk perception, which influences risk management. Other limitations include delays in programme implementation (Asante-Duah, 1993:26), but this can be addressed by performing a qualitative risk assessment based on the limited knowledge available, and basing assumptions on the precautionary principle. Standard forms of risk assessments, and regulations based on risk assessments, should disclose the limitations of the assessment and make such limitations available for public scrutiny, so that the potential unwise use of risk assessments can be avoided.

3.5.3.1.1 Uncertainty

According to Hunt (1998:47), risk assessment is a complex process that involves much judgement in the face of uncertainty. Pleus *et al.* (1998:5) state that risk assessment can be a very valuable tool in the regulatory process, which can enable businesses and governmental organisations to set realistic, protective environmental controls in place. However, risk assessment depends critically on the quality of the information that provides the basis for the analysis. Some information is well-developed and highly reliable, but some is not, and where scientific data are sparse, uncertainty is greater, and qualitative estimations, such as safety factors are used. Greater uncertainty causes incorrect risk estimation, a problem that can only be overcome by obtaining more or better scientific information or by recognising uncertainty and addressing it as part of the process. Furthermore, where numeric results are produced by the risk assessment, there is a tendency to rely overmuch on these values, which are no more than estimates determined in the face of uncertainty. Such an over-reliance on numerical values can create a false sense of accuracy, and assumptions and limitations of the modelling or assessment should be properly recognised and acknowledged. Farmer (1997:6) identifies some of the reasons why uncertainty exists in dealing with environmental pollution:

1. Lack of time to collect sufficient information.
2. The highly complex nature of environmental systems limits the ability to predict their responses.
3. Some aspects of the environment are still poorly understood. This is particularly true for the marine and geohydrological environment.
4. Undertaking experimental studies to obtain sufficient information might mean manipulating the very aspects of the environment that need to be protected.
5. Significant practical problems in obtaining data, especially over time, since some environmental effects, such as those of the geohydrological environment, only present after long periods.
6. The cost of obtaining sufficient information may outweigh the extent (or even cost) of the risk, or the obvious risk-reduction measure, itself.

When dealing with uncertainty in risk assessments, the precautionary principle should be followed as a starting point, after which the input from monitoring and further assessments should be used to iterate the risk assessment process.

3.5.3.1.2 Risk Perception

Risk perception is an issue that affects risk management, unlike uncertainty, which influences the outcome of risk assessment. Hunt (1998:30) notes that the objective/subjective debate is centered around the idea of "risk", not the notion of "hazard", i.e. it is commonly accepted that hazards and their realisation, are 'objective', but risk is a far more subjective idea involving much human judgement. The UK Guidelines (DoE, 1998:32,77) warn of factors (listed in Table 7) that may influence a risk management decision due to an individual's perception of a particular risk. These perception factors may influence the objectiveness of the risk management decision, especially if the decision to be made is politically loaded. To ensure that their influence does not play a detrimental role during risk analysis, it is important that the processes followed during the analysis are objective, logical, and understandable. If not, the final outcome of the risk assessment may be affected, resulting in inaccurate input into the risk management process. Hunt (1998:92) observes that a key feature in addressing the potential influence of risk perception factors is public involvement and risk communication, particularly in order to develop and maintain trust in the process. Furthermore, he stresses the importance of language usage in risk assessment, particularly with respect to the use of language that accurately and objectively describes and reflects the estimated risk.

Table 7: Some factors influencing Risk Perception

Familiarity:	People tend to underestimate risks that are familiar to them and to overestimate those that are unfamiliar. For example, although the participants in rugby and hang gliding have a fair idea of the risks they take, the general public underestimates the risk of a rugby injury and overestimates the risk of an accident in hang gliding.
Control:	Risk from an activity over which people have control is underestimated in comparison to risk from activities in which they are in other people's hands. Despite published statistics on fatalities, driving a car is considered safer than flying an aeroplane. Moreover, people demand greater protection from events over which they have no control.
Proximity in space:	People may overestimate the risks of something that might occur near them as opposed to activities occurring at a location remote to them. This is one of the factors in the "NIMBY" syndrome.
Proximity in time:	People tend to ignore the effects of risks that are going to arise much later in time, and even more so if they will not be realised within their own generation's lifetime.
The dread factor:	People exaggerate the risks associated with phenomena they do not understand. Moreover, they also demand greater protection from such phenomena (compare risks associated with machinery to those associated with radiation).
The scale factor:	The media is often more concerned about one large scale or emotional consequence than about a number of smaller consequences which add up to a greater overall consequence. This has the effect that the attention of the public, and especially politicians, is focussed more on large-scale activities.

The UK Guidelines (DoE, 1998:78) state that provision must be made in the risk analysis process for the identification of these factors, so that decision-makers can guard against misinterpretations arising from perception factors, as well as from an over-reliance on expert assessments which could be riddled with uncertainty.

3.5.3.2 ADVANTAGES OF RISK ASSESSMENT AND MANAGEMENT HARMONISATION

Risk analysis is the process of making decisions (risk management), based on the outcome of an assessment that is as objective as possible. The Brundtland Report (1987, in Farmer, 1997:6) sees the tool of risk assessment as assisting decision-making under uncertainty:

> "Risk assessment is one of the great challenges in sustainable development policy; the best available science is required to identify hazards and their potential consequences, and to weigh up the degree of uncertainty. Where appropriate (e.g. where there is uncertainty combined with the possibility of the irreversible loss of valued resources), actions should be based on the **precautionary principle** if the balance of likely costs and benefits justifies it. Even then, the action taken and the costs incurred should be in proportion to the risk. Action justified on the precautionary principle can be thought of as an insurance premium that everyone pays to protect something of value."

Asante-Duah (1993:26) states that risk assessment has several specific benefits, and its major advantages include the following:

⇒ Identifies and ranks all existing and anticipated potential hazards and failure modes;

⇒ Explicitly considers all current and future exposure scenarios;

⇒ Facilitates determination of cost effective risk-reduction through remedial alternatives and/or risk management and preventative programmes; and

⇒ Identifies and analyses sources of uncertainties.

According to Hunt (1998:66), the use of estimated risk values is considered to hold the promise of rational decision-making (management) in a range of circumstances:

- When making investment decisions to improve health and safety, the aim is to maximise the risk-reduction achieved against the investment.
- When there are different options for achieving the same desired improvement to environmental conditions the risk-reduction for the cost incurred should also be maximised.
- When the likelihood of a hazard being realised is judged to be negligible, investment to remove it may not appear sensible.

Asante-Duah (1993:9) asserts correctly that since waste management planning is becoming less conceptual and more quantitative, risk assessment is becoming more appropriate for use in the decision-making process. Hunt (1998:67) agrees, stating that management decisions may relate to issues such as:

⇒ The acceptability of risk in particular circumstances;

⇒ The prioritisation of certain situations and risk-reduction measures; and

⇒ The different options from which to select the BPEO to achieve risk-reduction.

Most important, risk assessment can provide regulatory decision-makers with the assurance that their regulatory systems and decisions are working properly. Risk assessment can be used to identify "real" risks, as opposed to perceived risks. It must be used to set ranges of acceptable risk, and to evaluate engineering measures for their effectiveness in achieving acceptable risk-reduction. According to Pleus *et al.* (1998:4), the primary benefit of using risk assessment in developing a regulatory system is that it provides for traceable regulations and requirements for particular facilities. Risk assessment can provide a structure for scientifically sound regulation that reflects the best scientific evidence of the risks of uncontrolled environmental, health, and safety conditions, as well as the likely effectiveness of appropriate management strategies. The key consideration is the ability of a risk assessment process to provide a scientific structure and framework to regulatory decision-making. Risk assessment can also provide a neutral scientific means by which to quantify the population's existing preferences regarding acceptable risk, and to vary what constitutes acceptable risk depending on conditions and circumstances. Pleus *et al.* (1998:5) observe correctly that where regulatory decision-making systems are developed without reference to formal risk assessment, industry will either be forced to over-invest or be allowed to under-invest in risk prevention measures, which results from an over-reliance on engineering solutions. Regulatory systems that are not risk-based may cause an inaccurate picture of the risks caused by the activity before the application of the engineered control measures, as well as ignorance regarding the residual risks remaining after application of the technology. In the absence of information about residual risks, there may be a lack of pressure to innovate or improve on existing regulatory control strategies and systems, leading to an excess of risk remaining after application of control measures and mechanisms.

Therefore, failure to use formal risk analysis in developing regulatory systems is likely to result in a failure to adapt existing regulatory systems to the latest available information about the hazards of particular substances, and an over- or under-investment in protective technologies, leading in both instances to a less efficient outcome in the longer term.

3.6 SUMMARY

The regulatory systems used to determine the potential effects of disposal or discharge of waste must be aimed at highlighting waste streams of concern, and should also indicate the most sustainable medium of disposal (venting into the atmosphere, disposal on land or discharge into a water resource), as well as the method of disposal, e.g. pre-treatment with special technologies. The outcome of these assessment approaches should direct waste minimisation strategies to where they are important, and should provide an incentive for the implementation of such strategies (Law, 1996:108).

The challenge set by the Constitution, namely to prevent pollution whilst ensuring sustainable use of the environment, is incorporated into the NWA through the concept of optimum beneficial use, which alludes to a systematic tiered decision-making framework. The NEMA also focuses on this concept, requiring the application of a risk-averse and cautious approach in the determining of such optimum use, and requiring the harmonisation of actions relating to the environment. The use of water for the discharge of waste is a valuable commodity, for which a use cost can be charged. Also important is the Constitutional requirement that decisions should be fair and transparent, and that administrative action should be just. This implies that an approach based on the principles of a harmonised risk analysis framework should be taken in the evaluation of applications to use the environment for waste disposal or discharge. The assessment of the potential impacts should take the characteristics of the source and the receiving environment into account, and on the basis of the outcome of the assessment, taking cognisance of uncertainty, as well as political and socio-economic factors, a decision should be made regarding the BPEO for the management of the specific waste stream.

The effectiveness of the existing procedures used to determine whether a disposal or discharge will be sustainable and legal will be evaluated in the next chapter on the basis of the practical implications of the principles of sustainability in relation to decision-making.

CHAPTER 4: EVALUATION OF EXISTING APPROACHES

4.1 INTRODUCTION

Before the promulgation of the NWA, two separate legislative tools regulated waste disposal and discharge actions, although the Department of Water Affairs and Forestry administrated both. Section 20 of the ECA controlled the disposal of certain waste types onto land under specified conditions, and s21 of the Water Act 54 of 1956 controlled the discharge of industrial effluent (water containing waste), usually into a water resource. On the basis of these two different statutory requirements, two different decision-making and assessment approaches were developed to assess the potential impact of a waste disposal or discharge, namely:

- A mechanism to determine the impact of discharging waste or water containing waste resulting from industrial activity in terms of s21 of the Water Act of 1956, as described in the document "Procedures to Assess Effluent Discharge Impacts" (DWAF, 1995); and
- A mechanism to determine the acceptability of the disposal of a particular waste stream in a specific waste disposal site, as identified under s20 of the ECA, as described in the documents "Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste" (DWAF, 1998b) and "Minimum Requirements for Waste disposal by landfill" (DWAF, 1998c).

A short description of each of these approaches has been provided in chapter 1. In the current chapter, criteria for the evaluation of these approaches are determined according to the discussions in the preceding chapters on the practical application of the principles of sustainability and the applicable legal requirements. Thereafter, an evaluative description of each of the current approaches is provided, highlighting individual advantages and shortcomings where necessary. Following this, the approaches are evaluated in a comparative manner against the criteria that have been established. Since these approaches were established before the promulgation of the NWA, this could be regarded as an "unfair" evaluation, however necessary it is to determine the components of a future integrated approach under the NWA that could incorporate the advantages of the current approaches. Finally, the implications of the lack of an integrated approach are illustrated.

4.2 CRITERIA FOR EVALUATION

The principles of sustainability have been identified in section 2.2.1, and their practical implications for waste disposal and discharge management have been discussed in previous chapters. The concepts underpinning these principles are briefly summarised in Table 8 below, after which evaluation criteria, based on the implications and practical application of these principles, as well as the applicable legislation, are deduced in Table 9 (pages 62 – 64), based on the discussions contained in chapters 2 and 3.

Table 8: Practical application of the Principles of Sustainability

Principle	Short description
Precautionary Principle	The precautionary principle is based on the age-old adage that "prevention is better (and uses fewer resources) than cure" (DoE, 1998:45). The precautionary approach holds that any waste is regarded as a hazardous substance that will cause pollution when discharged or disposed of, until proven not to be hazardous and not to cause pollution when discharged, but to be a sustainable use of the resource into or onto which it is discarded. The precautionary principle is a pro-active approach aimed at avoiding impacts and reducing risks before they become a reality. There is no more effective way of dealing with waste and preventing pollution than reducing the amount generated in the first place (Law, 1996:102).
Polluter Pays Principle	Both the principle of "polluter pays" and that of "internalisation of external costs" (which are closely related, but not entirely the same) hold that the costs associated with the burden of proof, as well as with the implementation of measures aimed at the prevention or remediation of pollution will always be that of the generator of the waste in question (DWAF, 1998b: 5). The polluter pays principle was formally adopted by the Nations of the World in 1992, and principle 16 of the Rio Declaration (UNCED:1992) states that "National Authorities should endeavour to **promote the internalisation of environmental costs** and the use of economic instruments, taking into account that **the polluter should, in principle, bear the cost of the pollution**" (Bredenhann & Garlipp, 1998:675). This principle also implies that the generator of the waste is responsible for the costs associated with its transport, treatment and disposal or discharge, even when another party has been contracted to manage these aspects on his behalf (DWAF, 1998b:5). The costs incurred with the action taken are for the account of the generator, it should be in proportion to the risk. It is important to note that the polluter pays principle does not imply that anyone can pollute as long as they can pay (Farmer, 1997:12). The principle, and the market benefits that result, must be used alongside a system of environmental standards and other measures that may prohibit seriously harmful polluting activities altogether, and which must be incorporated into the assessment and decision-making procedure.
"Cradle to Grave" Principle	This principle is often referred to as the "Duty of Care" principle, which implies that the generator of waste incurs the duty of caring for that waste even before it is generated, and is responsible for the fate of the generated waste under all circumstances. The principle imposes a duty on any person to act with "due diligence" in order to avoid damage or harm to others or to the environment, and can be compared to the South African law of *delict* (Bredenhann & Garlipp, 1998:676). The generator of waste therefore retains the ultimate responsibility for ensuring that his waste is classified, handled, stored, transported and disposed of or discharged, according to legislation and in an environmentally sound and responsible manner (DWAF, 1998b:5).
Integrated and Holistic Approach	One of the objectives of Agenda 21 (DEAT, 1998a:15, 20, 35, 56) is to restructure the decision-making process so that consideration of all aspects (socio-economic, environmental, etc) is fully integrated. It also requires an improvement in the interaction between the sciences and decision-making, using the precautionary approach to address uncertainty especially with respect to selecting the best option, (DEAT, 1998a:61). Agenda 21 furthermore states that an interactive, iterative and multi-sectoral approach must be followed that integrates technological, socio-economic, environmental and health considerations (DEAT, 1998a:35, 37) for all components of the water resource, including the subsurface portion there-of.
Carrying Capacity	This principle has been explored in detail in section 2.3.1, and is related to the optimum use (or "maximum sustained yield" (Fuggle and Rabie, 1994:51)) of the resource. Decisions to allow water use under governance of a licence in terms of the NWA must be based on the concept of optimum beneficial use, which can be related to the concept of optimum exposure introduced in chapter 2.
Consideration of Alternatives	The chosen management option should not merely 'shift' the problem from one environmental component to the other, but should indeed be the best practical environmental option (BPEO). For waste management, this principle implies that waste disposal to a storage facility may not necessarily be the BPEO, and that the manager of a company must consider other alternatives regarding the management of his waste, such as pre-treatment to allow discharge in a water resource.
Continuous Improvement	The principle of continuous improvement entails the ongoing betterment of all factors relating to the management of the disposal or discharge action, including the procedure itself, the criteria used in the assessment and decision-making approach, and the level of the assessment. According to Fuggle & Rabie (1994:617), policy on acceptable levels of exposure should continuously be revised and updated with new scientific knowledge, which in some cases may lead to more stringent criteria, or may show that some criteria have been unnecessarily restrictive.
Accountability and Liability	Since the polluter pays for pollution, this principle entails that those responsible for allowing polluting actions can be held criminally liable or civilly responsible for the effects of the action. The generator of waste must be able to prove that the impacts of its waste disposal or discharge has been determined correctly, and that his waste is handled in a responsible manner before its disposal in an appropriate facility or discharge into a water resource. A procedure for determining the acceptability of such disposal must therefore be one in which those involved in such determining can be held accountable, and which will specify a level of optimum exposure above which a generator of waste can be held liable for pollution, and its associated costs.
Transparency and Democracy	This principle requires public involvement in the decision-making process, and according to Hunt (1998:92), the approach must make provision for the problem of trust as a key factor in understanding risk and effectively participating in decision-making. Creating and maintaining trust goes far beyond public relations and two-way communication, and requires an approach that moves away from the notion of assessment and management being purely scientific exercises.

Table 9: Criteria for the evaluation of existing approaches based on legislation and Sustainability Principles

	Evaluation criterion	Recognition of evaluation criterion: Constitution	NWA	NEMA	Precautionary	Polluter pays	Cradle to grave	Integrated & holistic	Carrying capacity	Alternatives	Continuous improvement	Accountability & liability	Transparent & democratic
	Decision-making and assessment framework												
1.	Is the decision-making framework based on the hierarchy of options for decision-making for sustainable waste management, addressing **waste minimisation** initiatives as a first priority before determining **disposal or discharge management** options?	✓	✓	✓	✓	✓	✓	✓		✓	✓		
2.	Does it contain a **strong procedural approach** for the assessment of risks to determine **disposal or discharge management** options?	✓	✓	✓	✓			✓	✓	✓		✓	
2.1.	Does it contain **strict prescriptions** regarding how to deal with extremely hazardous sources in order to protect **public safety** (e.g. waste streams of concern that **cannot be disposed** of **or discharged** into the environment)?	✓	✓	✓	✓	✓	✓	✓				✓	
3.	Does the decision-making framework use the **same principles** (e.g. regard the water resource as **indivisible**) to assess the impacts of disposal or discharge actions on the different components of the environment in an integrated manner?			✓	✓			✓	✓			✓	
4.	Does the decision-making framework address **proposed, existing and historical** disposal or discharge actions**?**	✓	✓	✓	✓		✓	✓	✓				
5.	Are decisions made on the basis of a political determination of **acceptable risk to the human population**?	✓	✓	✓	✓	✓		✓	✓			✓	✓
5.1.	Is harm to humans prevented by the **acceptable risk** determined?	✓	✓	✓	✓			✓				✓	✓
5.2.	Is the acceptable risk aimed at establishing a **clear cut-off point** to distinguish between sustainable use and pollution?	✓	✓	✓	✓	✓		✓	✓			✓	
5.3.	Are **optimum use levels,** specified in **optimum exposure concentrations** and **environmental protection criteria** deduced from the acceptable risk?	✓	✓	✓	✓	✓		✓	✓	✓		✓	
5.4.	Does the mechanism set acceptable **levels for cleanup** of contaminated areas and remediation of polluting discharges on the basis of the acceptable risk?		✓		✓	✓	✓					✓	
6.	Does the decision-making framework contain a scientific determination of the ***de minimis*** risk?	✓	✓	✓	✓		✓	✓	✓				
6.1.	Is the *de minimis* risk used to deduce **conservative threshold exposure levels,** specified as discharge concentration **standards** or fatal flaw **criteria**, below which the introduction of a substance into the environment does not require regulatory involvement?	✓	✓	✓	✓	✓		✓	✓	✓		✓	
	Assessment procedure												
7.	Does the procedure **identify all potential hazards and exposure scenarios** based on the conservative exposure levels and criteria set as thresholds?	✓	✓	✓	✓	✓	✓		✓			✓	
7.1.	Does the **identification** address hazards posed by **all potential waste sources**?	✓			✓	✓	✓	✓				✓	
7.2.	Does the **identification** address **characteristics of the receiving environment** that could be particularly vulnerable to exposure and that **cannot be used for the disposal** or discharge of waste?	✓	✓	✓	✓			✓	✓			✓	
8.	Does the procedure follow a multi-media and multi-disciplinary approach, integrating inputs from across scientific boundaries in the assessment of the **hazard** posed by the waste, and the **exposure** of the receiving environment?			✓			✓	✓		✓		✓	
9.	Are both the **source** posing the **hazard** and **the exposure** of the **environment** assessed in an integrated & harmonised manner?			✓	✓	✓		✓		✓			
10.	Does the **hazard assessment** of the source contain an evaluation of the **intrinsic hazard posed by the waste,** based on characteristics such as volume, concentration, toxicological properties and additional factors (liquid or solid content) that will influence the risk?		✓		✓	✓	✓	✓				✓	
10.1.	Does the hazard assessment **categorise** waste streams in order to facilitate **prioritisation** of regulatory intervention?			✓	✓	✓		✓		✓	✓	✓	
10.2.	Does the hazard assessment evaluate **individual hazards** of individual constituents in separate waste streams, as well as **cumulative impacts** of all constituents in a waste stream stream/substance or combination of waste streams/substances to be disposed of?		✓		✓		✓	✓				✓	
10.3.	Does the hazard assessment determine the **potential hazard** posed by a product during its use, as well as take the **long-term effects** once it becomes a waste into consideration throughout its product, project and service **life cycles**?	✓		✓	✓		✓	✓		✓	✓		

Table 9 (continued): Criteria for the evaluation of existing approaches based on legislation and Sustainability Principles

Evaluation criterion	Recognition of evaluation criterion											
	Constitution	NWA	NEMA	Precautionary	Polluter pays	Cradle to grave	Integrated & holistic	Carrying capacity	Alternatives	Continuous improvement	Accountability & liability	Transparent & democratic
11. Does the **exposure assessment** contain an evaluation of the **site-specific characteristics of the resource** as receiving environment and the different environmental conditions that could increase or decrease the risk?		✓		✓			✓	✓			✓	
11.1. Does the **exposure** assessment **categorise** the receiving environment on the basis of its vulnerability or assimilative capacity in order to facilitate **prioritisation** of regulatory intervention?		✓		✓			✓	✓	✓		✓	
12. Does it take cognisance of the mitigatory effects of the implementation of **risk-reduction and environmental protection measures** (safeguards or **preventative measures** implemented at the cost of the generator of the waste), in determining the exposure?		✓			✓		✓		✓	✓	✓	
12.1. Is the standard of **design, operation and maintenance** (duty of care) of the treatment or disposal facility taken into consideration in the assessment of actual exposure?		✓		✓	✓	✓	✓			✓		
13. Does the procedure **estimate the actual risk** of the disposal or discharge of a waste into a particular receiving environment by comparing the results of the hazard assessment with the results of the exposure assessment?			✓	✓	✓		✓	✓			✓	
14. Does it make provision for different **levels of hazard and exposure assessments**, namely qualitative, semi-quantitative or quantitative, depending on the urgency of the decision, the severity of the impact, and the level of information provided?		✓		✓	✓		✓			✓	✓	
14.1. Does each progressive tier of assessment require a more detailed investigation aimed at gathering **information** in order to prove that the nature of the risk is of a lesser extent than the conservative assumption?		✓		✓	✓		✓			✓	✓	
14.2. Does it make provision for the **quick qualitative determination** of actual or potential risks under **emergency conditions** i.e. when there is not enough time to collect more information regarding the potential impacts?		✓		✓	✓		✓				✓	
14.3. Does it make provision for the **semi-quantitative determination** of actual or potential risks according to a prescribed calculation procedure based on accurate assumptions and models?		✓		✓	✓		✓				✓	
14.4. Does it make provision for the **quantitative determination** of actual or potential risks through which the applicant can make use of additional models, simulations, fault trees etc, to provide an accurate estimation of the actual or potential risk?		✓		✓	✓		✓				✓	
Decision-making considerations												
15. Does it involve **risk characterisation**, where the estimated risk of a specific disposal or discharge action is **compared** with the acceptable risk in order to determine the BPEO for optimum use?			✓	✓			✓	✓	✓	✓	✓	✓
15.1. Does it make provision for the estimation of potential or actual risks depending on the disposal or discharge of specific waste into different environmental media (i.e. air, land, surface water, marine environment), thereby indicating the BPEO regarding the correct **environmental medium** for the disposal or discharge?			✓	✓	✓		✓	✓	✓		✓	
15.2. Does it indicate what the BPEO for the **method of treatment** (e.g. desalination, ash-blending etc) prior to disposal or discharge should be, and does this, in some instances, lead to the implementation of waste minimisation measures?		✓		✓	✓		✓		✓	✓	✓	
15.3. Does it indicate the **BPEO** for the actual method of **disposal** (e.g. mono-disposal, co-disposal, surface impoundment etc.) **or discharge** (e.g. continuous flow or controlled release) of the waste stream?		✓		✓	✓	✓	✓		✓	✓		
15.4. Does it give an indication of the BPEO for the **remediation** and rehabilitation of existing disposal or discharge actions that are causing pollution, such as **contaminated areas and historical discharge actions**?		✓		✓	✓		✓	✓	✓			
16. Is the option that provides the **most favourable comparison** between estimated risk and acceptable risk regarded as the most **sustainable BPEO,** provided that the estimated risk is less than the actual risk?			✓	✓	✓		✓		✓		✓	
17. Does it place the "**burden of proof**" squarely on the shoulders of the person who is or will be undertaking activities that might affect human health or the environment to demonstrate that such activities will result in insignificant or negligible harm?		✓		✓	✓				✓	✓	✓	

Table 9 (continued): Criteria for the evaluation of existing approaches based on legislation and Sustainability Principles

Evaluation criterion	Recognition of evaluation criterion: Constitution	NWA	NEMA	Precautionary	Polluter pays	Cradle to grave	Integrated & holistic	Carrying capacity	Alternatives	Continuous improvement	Accountability & liability	Transparent & democratic
18. Does it make provision for the use of **judgement** by the decision-making body regarding the management of risks in the face of **uncertainty**, from doubt regarding the accurateness of the information, or from any other source?		✓		✓	✓		✓		✓		✓	✓
18.1. Is the framework **reasonable and realistic**, requiring the **best available information** at the level that is necessary (depending on the severity of the estimated risk) to make an informed decision by a responsible authority that is accountable to broader society?	✓	✓		✓			✓				✓	✓
18.2. Does each progressive tier of assessment **reduce the level of judgement** required in the decision?	✓	✓		✓			✓				✓	✓
19. Does it contain a mechanism for the **verification** of information provided by the applicant in the assessment?				✓			✓				✓	✓
20. Does the mechanism determine **priorities** for regulatory involvement in existing disposal or discharge actions that cause pollution, so that limited resources can be allocated in a focussed manner?		✓		✓	✓				✓		✓	
21. Does it give an indication of the scale and level of application of the appropriate resource economics **(waste discharge charge)** that must be employed to prevent the continuation of polluting actions?		✓		✓	✓		✓		✓		✓	
22. Does it integrate the scientific assessment of the risk with **socio-economic** and **political** considerations when the decision is taken?		✓		✓			✓		✓		✓	✓
23. Does it provide for **public involvement** in the decision-making process by giving the affected sector of the public the opportunity to participate in the decision, and where appropriate, require that the optimum exposure levels for a specific area or action are made less or more strict than the politically acceptable risk determined nationally?		✓	✓				✓	✓	✓		✓	✓
23.1. Does it make provision for factors influencing **perceptions** of risk and environmental impacts, and effectively **communicate** these to the affected sector of the public?		✓					✓				✓	✓
23.2. Is information obtained during the assessment procedure made available to the public in a manner that is **understandable** to the lay person, although the intricacies of the processes contained in a system may be of a highly-evolved scientific nature, involving many complex sciences and models?	✓						✓				✓	✓
23.3. Does it make use of **terminology** that does not create confusion due to its common usage (e.g. "contamination") or emotional connotations (e.g. "hazardous/toxic"), i.e. does it make use of language that accurately describes the actual hazards posed, the protection offered by safeguards or environmental factors, and the different risks resulting, in terms of their acceptability?							✓				✓	✓
General considerations												
24. Is the assessment and decision-making framework itself continually improved by comparison of the optimum exposure levels set with actual data, and re-evaluated on an ongoing basis in terms of this improved **scientific knowledge base**?		✓					✓	✓		✓	✓	
24.1. Are assumptions contained in the prescribed semi-quantitative hazard and exposure assessment continuously reassessed on the basis of new or improved scientific knowledge?			✓				✓	✓		✓	✓	
25. Is the information base supplemented with **monitoring data**, once the decision is implemented, and is a regular **re-assessment** of the actual impacts of the action conducted on the basis of this data?			✓				✓	✓		✓	✓	

The current approaches can be evaluated to establish their effectiveness in ensuring that disposal and discharge actions are sustainable as required in terms of the applicable legislation, on the basis of the criteria established above. This evaluation is done initially by highlighting certain factors during the individual description of each approach, and thereafter in a comparative manner.

4.3 PROCEDURES FOR THE ASSESSMENT OF EFFLUENT DISCHARGE IMPACTS

The Water Act 54 of 1956 was based largely on only the "Command and Control" approach (DWAF, 1991:18), and did not contain a definition of pollution, only the concept of a "pollution incident": "any incident resulting in the likelihood of water being polluted in such a manner as to be hazardous to human or animal life or cause material damage to the property of any person who has the right to the use of such water". Although waste was not defined in the Act, the word "effluent" was defined as: "Residual water or any liquid produced by or resulting from the use of water for industrial purposes, including any substance dissolved or suspended there-in, but excluding any liquid produced for commercial purposes". Section 21 of this Act compelled all persons using water for industrial purposes to purify such water or effluent so that it complied with the standards prescribed by the Minister by Notice in the Government Gazette, and subsequently to dispose of it in a controlled manner in the stream of origin, so that it would be available for re-use. The standards had to be determined by the South African Bureau of Standards (SABS), and the current standards, namely the "General Effluent Standard", "Special Effluent Standard" and "Special Standard for Phosphate", are described in Government Notice 991 of 1984 (RSA, 1984).

Unfortunately, the definition of "effluent" prevented many waste streams, for example municipal storm water containing high levels of organic loads and lead, and liquids, such as industrial acids, produced for commercial purposes from being subject to the provisions of s21 of the Act (Fuggle & Rabie, 1994:487). It could be argued that other sections in the Act could regulate such waste, for example s22, which stipulated that any person who had control over land on which anything was done which involved a substance capable of causing pollution, had to take steps to prevent water from becoming polluted by such a substance. Since the word "pollution" was not defined in the Act, the enforcement of these provisions was, however, almost impossible. Fuggle and Rabie (1994: 608) maintain that little is known about the health effects of the proliferation and variety of unidentified and potentially hazardous, if not toxic, chemicals that enter the water supply from sources such as effluent treatment plants, sewerage works etc when they are not effectively removed at these facilities. Where freshwater resources are limited, as in South Africa, a greater supply of water may be drawn from rivers and ground water that may be polluted from a range of toxic or hazardous substances from domestic, industrial and agricultural waste water sources. Examples include nitrates from agricultural practices and septic tank sewer systems, tri-halomethanes from the chlorination of water with a high organic content and, the latest scare, oestrogen-simulators from sewerage treatment works (Fuggle and Rabie, 1994: 608 and Williams, Jürgens and Johnson, 1999:1663).

4.3.1 HIERARCHY OF DECISION-MAKING

Those persons who were subject to the provisions of s21 could apply to be **exempted** from them, and had to follow a **prescribed** procedure for such an application, as described in the document "Procedures to Assess Effluent Discharge Impacts" (PAEDI) (DWAF, 1995). This entailed that the applicant demonstrate that all efforts had been made to avoid, reduce, re-use, recycle, detoxify, neutralise and treat the effluent, and that the impact of discharging the effluent will not cause adverse effects on the water resource. Although the Water Act of 1956 had been superseded by the NWA, PAEDI is still in use as the approach to assess these activities. It was published after the recognition of a policy document entitled "Water Quality Management Policies and Strategies in the RSA" (DWAF, 1991) that the general effluent standard alone was not effective in preventing deterioration of the country's water resources. This document suggested the combination of three approaches discussed below, namely:

- the pollution prevention approach;
- the Receiving Water Quality Objective (RWQO) approach; and
- the Uniform Effluent Standard (UES) approach,

These approaches are incorporated into a hierarchy of decision-making aimed at determining whether an exemption from s21 will be issued or not when an application for the discharge of effluent to a receiving water body is considered. The hierarchy is depicted schematically in Figure 13 (DWAF, 1995:10):

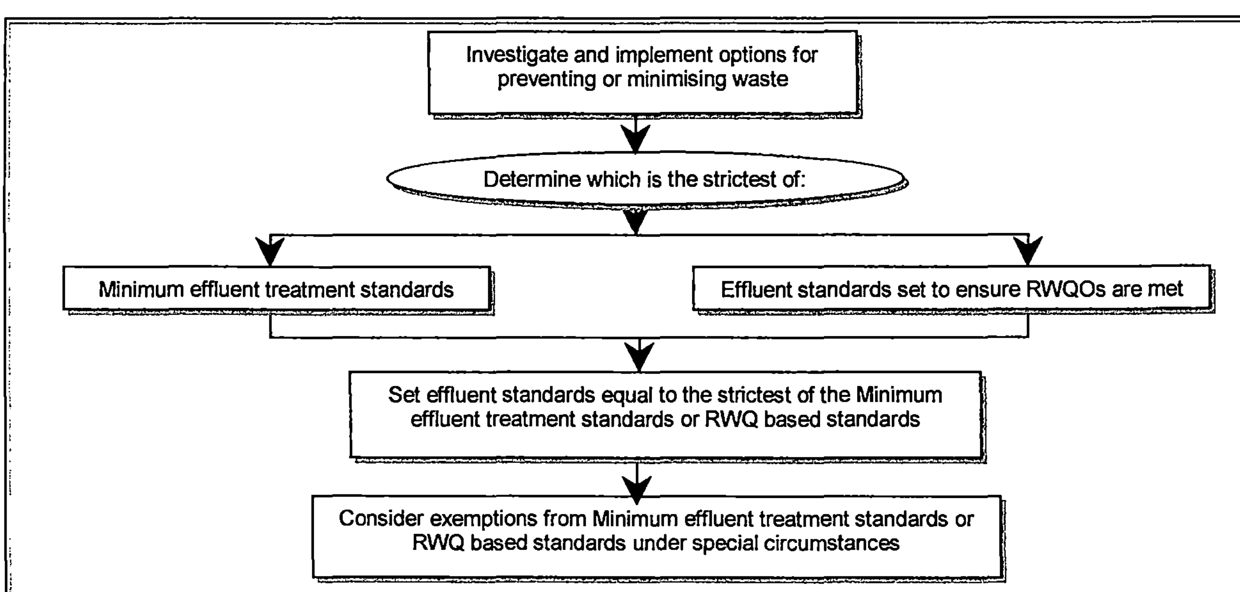

Figure 13: Decision-making hierarchy for applications to discharge an effluent

According to this hierarchy, options for preventing and minimising waste must first be investigated. Once these options have been exhausted, if there is still waste (effluent) to be discharged the waste water must meet whichever is the strictest, minimum effluent standards or receiving water quality-based standards. While minimum effluent standards are being investigated, the existing general effluent standard is still used as "minimum standard" (DWAF, 1995:10). The effect of the treated effluent on the receiving water's fitness for use is assessed against the desired receiving water quality. The effluent concentrations required to meet the receiving water quality objective (RWQO) are derived on the basis of an effluent discharge investigation. Such receiving water quality-based standards may be stricter than minimum effluent standards.

4.3.1.1 UNIFORM EFFLUENT STANDARD (UES) APPROACH

This approach aims to control the input of pollutants from point sources into the water environment, by requiring that effluents comply with uniform standards. The General Effluent Standard (RSA, 1984) is an example of a Uniform Effluent Standard. The UES approach can be applied usefully, is simple, understandable and straightforward to enforce, and minimises pollution from point sources. The UES approach is, however, inflexible, it does not take impacts on the receiving body of water into account, it ignores pollution arising from diffuse sources, it encourages end-of-pipe solutions, it is not cost effective and it does not encourage industries to locate themselves at environmentally advantageous locations (DWAF, 1991:12; Fuggle & Rabie, 1994:464).

4.3.1.2 RECEIVING WATER QUALITY OBJECTIVE (RWQO) APPROACH

This approach specifies the quality required for the receiving body of water and its users. It attempts to take the effects of both point sources and diffuse sources into account, and recognises the capability of the natural environment to take up or 'assimilate' certain pollutants into the biological cycle. Setting site-specific standards that take contributions from diffuse sources into account can effectively control point sources. The application of this approach is technologically more demanding than the UES approach because it requires thorough understanding of the fate of pollutants in, and of their impacts on the environment. In the domain of positively harmful substances, the RWQO approach is, however, ineffective, because of the difficulty of determining safe receiving water quality standards for these pollutants (Fuggle & Rabie, 1994:465). Also, DWAF has embraced the Polluter Pays principle in its combined approach policy (DWAF, 1991:19), but it has proved impossible to reconcile this principle with the RWQO approach.

4.3.1.3 POLLUTION PREVENTION APPROACH

This approach is specifically aimed at control of the handling and disposal of hazardous substances (DWAF, 1991:13) and pollutants that cannot be received favourably by the environment. The toxicity, persistence and capacity for bio-accumulation of some pollutants present major threats to the environment. Where too little information is available about the behaviour of a specific substance, it is assumed to be in the category of these pollutants. South Africa has yet to create a mechanism to identify this category of pollutants in relation to discharge into the water resource. In some countries, where such a mechanism had been implemented, this "list" has been extended to embrace all chemicals, which has evolved because of the high priority accorded to the anticipatory principle of pollution prevention.

4.3.2 ASSESSMENT PROCEDURE

The manner in which the effluent discharge investigation process functions, is that an applicant with the intention of discharging an effluent applies to DWAF for an authorisation in terms of the appropriate legislation. A "roadmap" of an effluent discharge investigation process is provided in PAEDI (DWAF 1995:30), and is illustrated in Figure 14 below. During this process, the RWQOs are set in consultation with the public and the potential water users in the catchment area.

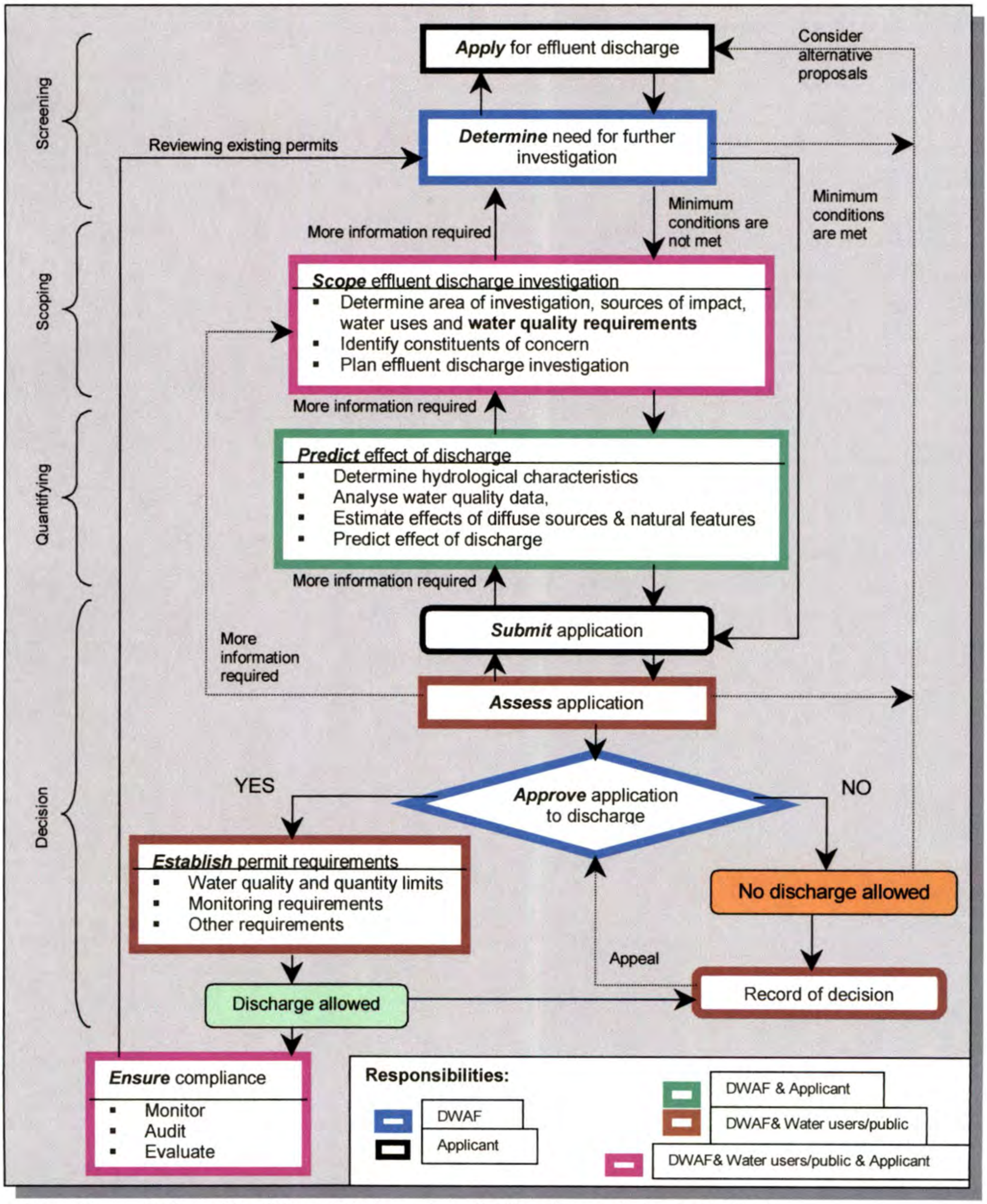

Figure 14: Outline of the Effluent Discharge Investigation Process in terms of PAEDI

These objectives are based on the water quality requirements for different water users published by DWAF in a series of documents collectively known as "South African Water Quality Guidelines" (DWAF, 1996b and 1996c), as well as on the requirements of the existing users in a catchment (DWAF, 1995:13). The documents contain a "Target Water Quality Guideline" (TWQG) for most constituents, and the objective when determining the RWQO is initially to set it at a level equal to either the existing water quality in the river, or the TWQG. It is said (DWAF, 1995:79) that the TWQG represents the "no effect" level, and that the objective is to maintain the quality of South Africa's water resources within the no effect range. The water quality objective may be set outside the TWQG, after the consideration of factors such as development objectives, land use and catchment characteristics (DWAF, 1995:14), and on the basis of the outcome of a detailed investigation. During such an investigation, the "Acceptable Water Quality Guidelines" (AWQG) must be taken into consideration in setting objectives. Once these objectives have been set, the applicant must then determine what the quality requirements of his proposed effluent discharge should be in order to meet these objectives at a specific point in the catchment. This determination can include the modelling of predicted impacts, which can be used to justify effluent discharge of lesser quality than the specific UES prescribed by regulation (RSA 1984), and the applicant can be exempted from the standard if such motivation is acceptable (DWAF, 1995:14, 166).

Such an exemption from the requirements of s21 of the Water Act of 1956 is considered under special circumstances, and as a last resort, but requires sufficient justification on technological, economic and socio-political grounds. However, although this combined approach has been in place for the past decade, very few industries have actually undertaken such an investigation. The main reasons for this is firstly that it is an extremely costly and time-consuming exercise. Furthermore, the TWQG for a specific constituent is different for each particular use. For example, the TWQG for Cadmium (a carcinogenic chemical) is 5,0 μg/l for domestic use, but for aquatic ecosystems, it is 0,40 μg/l. There is also confusion amongst practitioners regarding which water quality guideline to use in discussions with the public, and the AWQG is often used as a starting-point in the investigation, without any reference to the TWQG. Finally, the formal institution of a public participation body comprised of the water users in a catchment (a so-called "forum") to set the water quality objectives is not only time consuming, but becomes a small political battlefield (personal experience and communication with various water quality management personnel in DWAF). This could be partly owing to the fact that each water user present at the forum has his own personal objectives to achieve, which in most cases are in conflict with those of the applicant and/or DWAF. Weale (1992:46) describes this phenomenon as characteristic of the rational choice theory, where interest groups are more likely to advance their own interests in the absence of clear alternatives.

Although it is not clearly obvious, this procedure does contain elements of a risk-based approach, and does incorporate public participation mechanisms during the decision-making phase. Waste minimisation is addressed in the hierarchy of decision-making, and different levels of assessment can be conducted depending on the amount of information required. The mechanism unfortunately does not address all sources and types of waste, as defined in the NWA and in an integrated manner, it does not indicate the correct medium for disposal (land, sea, resource), it is furthermore less effective in assessing retrospective situations and it does not necessarily highlight the BPEO for risk-reduction.

4.4 MECHANISMS FOR DETERMINING WASTE DISPOSAL IMPACTS

Waste is defined in s1 of the ECA as: "any matter, (whether gaseous, liquid or solid, or any combination there-of) which from time to time may be proclaimed by the Minister [of Environment Affairs] by notice in the Gazette as an undesirable or superfluous by-product, emission, discharge, excretion, or residue of any process or treatment". Government Notice 1986 in Government Gazette 12703 of 24 August 1990 was issued to describe what is meant by "waste" in this context. However, this definition specifically **excludes** the following: water used for industrial purposes; any matter discharged into a septic tank or french drain sewerage system; building rubble used for filling or levelling purposes; any radio-active substances; any minerals, tailings, waste rock or slimes produced at a mine; or ash produced by or resulting from the generation of electricity. According to Peckham (1994:90), a substantial volume of potentially hazardous waste escapes regulation due to this definition, and this presents a considerable potential for environmental harm.

In terms of s20(1) of the ECA, no person may establish, provide or operate a disposal site without a **permit** issued by the Minister of Water Affairs and Forestry. Barnard (1997:226) states that the choice of department is appropriate, since the most severe and longer-term impact resulting from the disposal of waste on land is on the water environment, particularly the ground water environment. Furthermore, as discussed in chapter 2, the improper disposal of waste on land could have a substantially more detrimental effect on ground water quality than on any other part of the environment.

It is important to note that s20 of the ECA extends beyond the disposal of waste on land in a conventional waste disposal site, since s20(6) of the ECA states that nobody may dispose of waste except on a disposal site for which a permit has been issued in terms of s20(1), and also only in such a manner, or by means of a method, or subject to any condition, prescribed by the Minister. The definition of "disposal site" as contained in s1 of the Act is relevant in this respect: "a site used for the accumulation of waste with the purpose of disposing, **or treatment,** of such waste". This implies that a person treating waste for re-use or any other purpose may only do so after approval has been obtained from the Minister. In must also be noted that the Environmental Impact

Assessment (EIA) Regulations promulgated under ss21, 22 and 26 of the ECA must be complied with when applying for a permit under s20(1).

Due to the fact that the Notice specifying the definition of waste under the ECA was promulgated in 1990, all proposed landfill sites, operating landfill sites and sites closed after 1990 must be permitted under the ECA. Unfortunately, this however means that sites (or sections of sites) closed prior to 1990, or historically contaminated areas, cannot always be governed in terms of the ECA.

Section 20(3) of the ECA states that the Minister may demand any additional information from an applicant to enable him to make a decision regarding an application for a permit under s20(1) of the ECA. In Government Notice 1064 of 1994 (Policy on the Management of Hazardous Waste) reference is made to the establishment of "minimum requirements" or "standards" in relation to waste management practices. On the basis of these two provisions, the first edition of a trilogy of documents collectively known as "Minimum Requirements" was published in 1994, and updated with a second edition in October 1998. The documents in the series are "Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste" (MRHW) (DWAF, 1998b); "Minimum Requirements for Waste disposal by Landfill" (MRWD) (DWAF, 1998c); and "Minimum Requirements for Water Monitoring at Waste Management Facilities" (MRWM) (DWAF, 1998d). The Minimum Requirements incorporate the hierarchy of options for sustainable waste management, as discussed in chapter 2, and although not described explicitly, the approach of determining the acceptability of the disposal of a particular waste stream in a specific waste disposal site is implied. Because Minimum Requirements are not directly legally enforceable, some Requirements are contained in secondary legislation such as permit conditions, and an example of such a permit condition reads as follows:

2.1	Subject to the provision of condition 15, any portion of **the Site** which has been **constructed** or developed according to condition 3 of this Permit, **may be used for** the disposal of **all waste types** which are **classified** according to the latest edition of the **"Minimum Requirement" series of documents** as published by the Department as suitable for disposal at a G:L:B+ disposal facility, excluding those waste types listed in Annexure I.

Figure 15: Example of a permit condition that gives legal standing to a Minimum Requirement

The Minimum Requirements address the classification of waste streams, the siting, design construction, management, monitoring and rehabilitation of waste management facilities, as well as the procedure by which to apply for a permit (Peckham, 1994:96). It is said (DWAF, 1998c:1-1) that the Minimum Requirements are used to:

- Set out minimum procedures, actions and information required from a permit applicant during the process of permitting a proposed or existing waste disposal facility in terms of s20 of the ECA;

- Provide a point of departure from which environmentally acceptable waste disposal practices can be distinguished from environmentally unacceptable practices; and
- Provide the applicable standards or specifications that must be followed in the absence of any valid motivation to the contrary.

In the context of this study, it is necessary to evaluate the considerations contained in the documents, in relation to the source, the receiving environment, and the risk-reduction measures that are implemented to address the impacts of the waste disposal activity. As stated, the documents do not contain an assessment and decision-making approach from which to determine the correct disposal of a specific waste stream at a particular waste site, but certain elements of such a mechanism are incorporated in the documents, which will be explored and evaluated in the next two sections.

4.4.1 THE RECEIVING ENVIRONMENT: WASTE DISPOSAL FACILITIES

The publication of the Minimum Requirements, especially the document "Minimum Requirements for Waste Disposal by Landfill" has taken waste management in South Africa to a higher level of sustainability. This document outlines the procedure to be followed when applying for a permit, and addresses the siting, classification, design construction, management, monitoring and rehabilitation of waste management facilities. It also stipulates the procedures to be followed when investigating the potential impacts of establishing a new waste disposal site. During site selection, certain criteria termed "fatal flaws" can prevent the siting of a new waste disposal site in a specific location. Once all areas with fatal flaws have been eliminated, other aspects must also be considered during site selection, and these include economic, environmental and public acceptance criteria (DWAF, 1998c:4-6). Unfortunately, many existing waste disposal sites are still operational, in spite of the fact that they exhibit such fatal flaws. Also, there is no incentive for a site developer to select a site that will pose a low risk to the environment apart from eliminating fatal flaws, a fact that is of particular concern for the selection of hazardous waste sites, which are often ventures driven by economic considerations.

Waste disposal sites are classified according to the amount and type of waste that will be handled by the specific site (DWAF, 1998c: 3-5 and DWAF, 1998b:8-9): For new disposal sites, once these factors have been established, the MRWD prescribes certain design construction requirements. The B+ or B- factors used in the classification of general (G) disposal sites are determined by the potential for the site to generate leachate, but takes only climatic conditions, and not the moisture content of the waste to be disposed of at the site, into consideration. Should these climatic conditions suggest that the site has the potential to generate leachate, the site must be constructed with leachate management systems in its lining design. The lining designs that are specified in the MRWD have the objective of preventing pollution of adjacent surface and ground water with leachate (DWAF, 1998c:8-1). The site classification system applies regardless of whether a site is new and designed to the latest specifications, or has been in existence for decades, and exhibits fatal flaws. In order to evaluate the classification of waste disposal sites on the basis of the type of waste, it is necessary to evaluate the waste classification mechanism.

4.4.2 THE SOURCE: CLASSIFICATION OF WASTE

The source posing the hazard, namely the waste, is classified into two main classes, namely "general" waste and "hazardous" waste. Unfortunately, although the definitions of "general waste" in the glossaries of both the MRWD (DWAF, 1998c:G-4) and the MRHW (DWAF, 1998b:G-3) are similar, the description of the terms in the texts themselves differ (DWAF, 1998c:3-2), especially with regard to the disposal of medical waste. Furthermore, the glossaries (DWAF, 1998c:G-5 and DWAF, 1998b: G-4) contain two definitions for the term "hazardous waste", both of which differ from the descriptions in the texts. Therefore, the most applicable definitions contained in these glossaries are listed below for the purposes of clarity:

Term	Definition	Allowable disposal
General Waste	Waste that does not pose an immediate threat to public health or to the environment, i.e. household waste, builders' rubble, garden waste, dry industrial and commercial waste. It may however, with decomposition, infiltration and percolation, produce leachate with an unacceptable pollution potential.	May be disposed of in any site that is permitted in terms of s20 of the ECA (DWAF, 1998b:2-3)
Hazardous waste	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.	May only be disposed of in a hazardous waste landfill site (DWAF, 1998b:2-3)

The MRHW (DWAF: 1998b:2-3) however, states that all waste is potentially hazardous, and all industrial waste is therefore regarded as hazardous (subject to the outcome of a waste classification process) in spite of the definition of general waste. This presents an interesting problem, which is further complicated by the above definitions owing to the fact that they imply that any leachate produced at a site used solely for the disposal of general (domestic) waste may not be disposed of on the site, because it may be regarded as a hazardous waste. The definitions furthermore do not describe the potential hazard posed by the waste or how such hazard is to be assessed, since statements like "it can lead to serious pollution" and "causes an increase in mortality or illness" are difficult to interpret (DWAF, 1998b:A2-1). It is said that for this reason, hazardous waste is defined further through a classification process.

The waste classification system contained in the MRHW starts with an evaluation of the waste in terms of its avoidance, re-use, reclamation and treatment in order to **minimise** its potential impact on the environment. It is then identified and classified as outlined in Figure 16 below. The first step of the classification, namely to identify particular examples of waste as probably hazardous because of the industrial group or process from which it arises, may result in potentially hazardous waste's being omitted from the classification process because it does not arise from one of the listed processes. An example is the collection of fluorescent tubes from buildings and office blocks, which are disposed of on a large scale, and mostly in an uncontrolled manner.

The MRHW identifies and Classifies Hazardous waste by:

- Including **lists of substances and processes** that are likely to generate hazardous waste. This includes SABS Code 0228: "The identification and classification of dangerous goods and substances", which is derived from the International Maritime Code for the Transportation of Hazardous Goods (IMDG), a United Nations system for goods transported by sea. All waste containing these substances or generated by these processes or listed in the document is classified as potentially hazardous. It is stated that the absence of a substance or process from the lists does not necessarily imply that the waste containing such substance or generated by such process is not hazardous (DWAF, 1998b:A2-2).
- Following a **degree of hazard** approach. By using SABS Code 0228, substances are categorised into 9 classes, according to their most hazardous physical, chemical, or toxicological properties and according to characteristics such as flammability, corrosiveness, reactivity or toxicity, which are determined by means of prescribed tests and analyses. All classes of waste, except gases and some radioactive types of waste have to be tested ultimately against Class 6: Toxic and Infectious Substances. For some classes of waste, pre-treatment may be necessary to allow the waste to be evaluated according to the criteria set for Class 6 (DWAF, 1998b:6-3 –7-4, A2-2).
- Extending Class 6 of SABS Code 0228 to obtain a **Hazard Rating for disposal**. This is derived from the inherent acute and chronic toxicity of the compounds for mammals and the ecology and compared to a numerically calculated Estimated Environmental Concentration (EEC). It is said (DWAF, 1998b:A2-2) that the EEC is used to provide an exposure level and assimilative capacity, based on "total loading" in which the compound is regarded as hazardous above a threshold concentration known as the Acceptable Risk Level (ARL). This ARL is set scientifically at a risk of 3×10^{-5} aquatic mortality (DWAF, 1998b:8-5). The ARL is calculated at a tenth of the LC_{50} (lethal concentration that will cause 50% mortality) in an aquatic species, while the EEC is calculated by means of the following equation:

  EEC = Dose (g/ha/month) x 0.66
  (0,66 = factor derived from ratio of a substance in a weight of a body of water)
- Including a "**Delisting by Exemption**" approach. This entails that a Hazard Rating can be assigned to a waste stream by determining the mobile concentration through quantitative analysis, recognising the effects of treatment, re-analysis and re-calculation of the EEC (DWAF, 1998b:6-3 –7-4, A2-2). The quantitative analysis could be either the TCLP-test (for waste that contains organic material, or that will be disposed of in the presence of organic material), or the adapted Acid Rain test (for waste containing no organic compounds, that will be disposed in the absence of organic material).

Figure 16: Identification and classification of hazardous waste according to the Minimum Requirements

Waste that exhibits characteristics specified in Classes 1 – 5 and 7 and 8 of SABS Code 0228 is prohibited from being disposed of on land in a waste disposal site, unless it has been treated to reduce the risks associated with these characteristics, where-after its Hazard Rating must be determined according to the procedure prescribed in the MRHW for Class 6 (DWAF, 1998b:9-4). The determination of the Hazard Rating places the waste in a Hazard Group, which determines the category of landfill site in which it may be disposed of (DWAF, 1998b:8-3): waste from Hazard Groups 1 and 2 (extreme and high hazards) must be disposed of in a H:H landfill site, while waste from Hazard Groups 3 and 4 (medium and low hazards) may be disposed of in either a H:H or H:h landfill site.

The ARL is not calculated on the basis of user requirements, but is derived from toxicological principles, and therefore does not correspond with the "Acceptable Risk" concept introduced in chapter 2. It can better be compared with a threshold value set scientifically at the *de minimis* risk level. Unfortunately, as Fuggle and Rabie (1994:591) observe, of the millions of chemicals known, less than 1% have been characterised in terms of their toxicological effects on humans, and even less for aquatic toxicity. Furthermore, the literature often contains different LC_{50} values for the same substance, and since the LC_{50} value is used to determine the ARL, which will determine the final Hazard Rating and the correct waste disposal site, it is extremely important that that a uniform value be used.

The EEC must be calculated for each individual chemical substance in the waste stream, although a waste may contain complex mixtures of chemicals (Fuggle and Rabie, 1994:591), and their combined effects are not characterised. This means that for all waste streams disposed of on a particular site, a complete quantitative analysis must be conducted and the EEC must be calculated for all identified compounds. If the EEC is lower than the ARL, the disposal is regarded as acceptable for a specific waste site. However, if the EEC of any of these individual chemicals, even those found in trace amounts, is higher than the ARL, the risk posed by disposal is deemed unacceptable, and the waste must either be disposed of in a site that offers a higher degree of protection, or treated to reduce the risk and re-evaluated in terms of the classification procedure.

When the EEC of a chemical with a Hazard Rating of 1 (LC_{50} < 1 mg/l) is compared to the applicable ARL (0.1 x LC_{50}), and is found to be higher than the ARL, the waste must be classified as Hazard Group 1 and disposed of in a H:H site. Should it be lower than this ARL, the waste containing this chemical will be classified in Hazard Group 2, and must still be disposed in a H:H site. Only if the EEC is less than a tenth of the ARL will it be regarded as non-hazardous, and may be disposed in an approved General waste disposal site equipped with an appropriate leachate management system (DWAF, 1998b:A2-2).

When the EEC of a chemical with a Hazard Rating 2, 3 or 4 is calculated and found to be higher than the applicable ARL, the waste will have to be disposed of according to the appropriate Hazard Group (DWAF, 1998b:8-6). Should the EEC, however, be lower than this ARL, the waste containing this chemical will be regarded as non-hazardous, and may be disposed of in an approved General waste disposal site equipped with an appropriate leachate management system (DWAF, 1998b:A2-2).

The disposal of halogenated organic waste by means of encapsulation or landfill is only permitted in the absence of an incineration facility (DWAF, 1998b:9-4). It is unfortunate that no preference for either encapsulation or landfill is specified, since it is known that the compounds in such waste will attack the integrity of plastic lining systems, and their disposal on land has been restricted by the United States of America Environmental Protection Agency (US EPA) (Baldwin, 1997:15). Furthermore, with regard to medical and infectious waste, no distinction is made between bio-hazardous waste, as regulated under the Human Tissues Act, and other types of medical or infectious waste. Also, although the Minimum Requirements state that the hazardous effects of carcinogens are not related to their concentration in waste, the system allows for wastes with a carcinogen content of less than 1 % to be classified with a lower Hazard Rating.

For wastes that are not "delisted" to the desired Hazard Group, the concentration or volume of the waste must be decreased, or the size of the site or the length of the period of disposal can be increased, for the desired disposal to be approved. Unfortunately, increasing the time period or size of the site to allow for the approval of a classification actually increases, rather than decreases, the risk to the environment, is in conflict with the precautionary principle, and with the principle of containment adopted for hazardous landfill sites. By increasing the length of the period of disposal, the period of exposure is also increased, with the result being an increase in risk. Owing to the fact that the possible risks of high liquid content in waste are not assessed, but incorporated in the co-disposal ratio, many wastes with high liquid content which should have been treated and returned to the environment have been disposed of in an H:H, H:h or G disposal site, resulting in unmanageable quantities of leachate (See Figures 10 and 19, pages 35 and 85).

Another issue that must be explored is the calculation of a "**total load**". It is said (DWAF, 1998b:9-2) that the capacity of a landfill to accept a certain substance is determined by multiplying the monthly volume allowed per hectare in accordance with the calculated EEC, by 100. The figure reached is referred to as the "total load". The EEC for a specific substance (e.g. mercury) in each waste stream disposed of at the site must be added up, and when the total for a substance exceeds the EEC x 100, the site may no longer accept any waste streams containing that substance (DWAF, 1998b:8-8), although other wastes that do not contain the specific substance may still be disposed at the site. This principle is not applied to General waste sites accepting "delisted" wastes. The implementation of this requirement requires a detailed knowledge of all components of all waste streams entering a site, as well as an accounting system with which to determine when to stop accepting wastes containing a specific substance. In the example above, the actual implication of this requirement may entail that when the total load for mercury is reached, the site can no longer accept domestic waste, since there may be batteries containing mercury in the waste. This may result in a situation where no waste disposal site in the country is allowed to accept a certain substance any longer, for example mercury, or where there are no alternative sites available with the appropriate "capacity". This may lead to uncontrolled dumping.

The most important disadvantage is the lack of true risk estimation. Unfortunately, not all the existing waste disposal sites were designed and constructed according to the MRWD specifications. Although the hazard posed by the waste is determined almost quantitatively, this is not compared with the site-specific environmental conditions. This could result in the disposal of waste at a site that is neither selected, designed or operated in a manner that would offer adequate risk reduction. Furthermore, for retrospective classification of waste, a waste site can be classified as H:H, although no waste containing a severe acute risk to human health had ever been disposed of at the site. The waste disposed on the site could have a hazard rating of 1, for example when it contains more than 0.6 ppb of Dieldrin (a few empty cans of household pesticide). This is not only lower than the detection limit of most laboratory instruments, but causes perception problems amongst the affected public. For example, due to levels of Zinc exceeding the ARL at an ash disposal site in Durban, the site has to be classified as H:H, and the public were extremely concerned about "drums of green fuming stuff" in their neighbourhood.. Furthermore, if existing sites are classified based on the waste disposed on them according to the classification system described above, it may happen that a site used solely for the disposal of ash can obtain a H:H classification, which places it in the same category of a site accepting waste of a higher hazard category. This creates problems with respect to public perception.

In spite of the many difficulties with the classification of waste, it also has certain advantages. It has alerted generators of waste to the fact that waste does not have to be "toxic" to be regarded as hazardous, and is a much improved system than what was in place before the publication of the Minimum Requirements. The publication of design criteria in the MRWD has created a new category of waste disposal site, namely site that provides additional protection to the environment, as opposed to some existing sites which do not exhibit this feature and may pose a long term risk. The MRWD specifies certain standards for the management, operation and monitoring of a waste disposal site (DWAF, 1998c:10,11 and DWAF, 1998d). When a site is managed well, and has successfully implemented an environmental management system such as ISO 14001, the risk of an incident that might potentially cause pollution is significantly reduced. Such a site should be allowed to accept waste with a higher potential risk than badly managed sites, but operators cannot get recognition for responsibility under the current classification system.

Although the document (DWAF, 1998b:2-3) states that the system is based on the concept of risk, the above discussion suggests that this is not truly the case, and contains only some illustrations of shortcomings of the classification system. It does, however, also state some advantages of the system, which is evaluated in detail against the principles of sustainability in section 4.5 below.

4.5 COMPARATIVE EVALUATION OF THESE APPROACHES

In sections 4.3 and 4.4 above, the two approaches that are currently used to assess disposal or discharge actions were described and evaluated individually. It is however also necessary to compare the two approaches with each other in order to evaluate their performance in terms of the evaluation criteria established in section 4.2. At the outset, it must be stated that the mere fact that two different approaches exist is regarded as a serious shortcoming, since a single integrated and holistic approach is necessary to guide decision-making towards the BPEO. This comparative evaluation will therefore also explore some results of this lack of integration.

4.5.1 EVALUATION AGAINST THE PRINCIPLES OF SUSTAINABILITY

The criteria for evaluation, as outlined in Table 9 above (see pages 62 – 64), are used in Table 10 below to evaluate the performance of the two approaches with regard to the principles of sustainability and the new legal requirements. In considering this evaluation, it must, however, be kept in mind that the approaches were established before the promulgation of the new legislation, and were thus not written with the aim of addressing its requirements.

Table 10: Comparative evaluation of existing approaches against established criteria

Evaluation criterion	Minimum Requirements approach (ECA 73/1989)		PAEDI approach (Water Act 54/1956)	
Decision-making and assessment framework				
1. Addresses waste minimisation?	Although waste minimisation is included in the Hazardous Waste Management Process (DWAF, 1998b:2-2), the framework does not alert the generator to possible savings through the implementation of waste minimisation strategies (Law, 1996:103)	☺	The first step of the hierarchy of decision-making entails that the generator demonstrate his efforts towards the implementation of steps for the prevention and minimisation of waste, although the economic benefits of such steps are not evident to the generator.	☺
2. Strong procedural approach aimed at determining the BPEO?	The approach is aimed not at determining the BPEO for managing a specific type of waste, but rather at selecting the most appropriate waste disposal site, which precludes other management options.	☹	The approach is aimed not at determining the BPEO for managing a specific type of waste, but rather at achieving an acceptable effluent discharge situation	☹
2.1. Strict prescriptions regarding extremely hazardous sources?	The MRHW contains strict prescriptions regarding how to deal with wastes that poses an acute safety or health risk, and prohibits the disposal of such waste into the environment in a state that will cause the realisation of these risks of harm (DWAF, 1998b:9-1).	☺	It is assumed that effluents discharged into a water resource do not pose an acute safety or health risk, except from a bacteriological perspective, and for such waste the general effluent standard prescribes the allowable count of *Escheridia coli* bacteria to be 0.	😐
3. Integrated assessment of the indivisible water resource?	The framework focuses on the impacts on the ground water resource, although the surface water component is addressed during site selection and operational management	😐	The framework focuses on the surface water resource as receiving environment, although impacts on the ground water component is addressed during assessment of non-point sources (DWAF, 1995:143)	😐
4. Proposed, existing and historical disposal or discharge actions?	Aimed mostly at proposed disposal actions, although it can be used to evaluate existing disposal actions. Not really applicable to historical disposal actions, since the ECA is not applicable to sites that closed prior to 1990.	😐	Aimed mostly at proposed and existing discharge actions, although more effective for proposed actions than for existing actions. Can address historical disposal actions, e.g. disposal of effluent on land (evaporation dams, irrigation), by encouraging implementation of treatment technologies.	😐
5. Political determination of AR?	Acceptable risk is determined scientifically at a 1 in 300 000 mortality rate for the aquatic population.	☹	An acceptable range is set as Acceptable Water Quality Guideline (AWQG) values, but these are not based on a political decision on acceptable risk.	☹
5.1. AR set to prevent harm to humans?	Although the AR is aimed at the aquatic population, harm to humans is prevented by the use of SABS Code 0228 in the classification process, which addresses acute and chronic risks to human safety and health by preventing the disposal of carcinogenic and mutagenic substances.	😐	It is assumed that effluent that can be discharged into a river does not pose an immediate risk of harm to human safety. Risk of harm to human health, especially through the introduction of carcinogenic substances and bacteriological contaminants, is prevented where possible (DWAF, 1995:8), although not assessed explicitly.	😐
5.2. AR distinguishes between sustainable use & pollution?	Does not effectively distinguish between sustainable use and pollution, as is evident from the comparisons in Figures 17 and 18 below.	☹	Does not effectively distinguish between sustainable use and pollution, as is evident from the comparisons in Figures 17 and 18 below.	☹
5.3. Optimum use levels deduced from Acceptable Risk?	Although the Acceptable Risk is not determined at a political level, acceptable risk levels are established at 10% of the LC_{50} value. This cannot be regarded as an optimum use level. Furthermore, although LC_{50} values are available in the literature, different values are often available for the same substance.	😐	Since the AWQG values are said to be "acceptable", although they are not based on a political determination of Acceptable Risk it has to be assumed that they are regarded as optimum use levels. However, as outlined under 4.3.1.2 and 4.3.2 and illustrated in Figures 17 and 18 below, they do not represent optimum use as intended by the drafters of the NWA.	😐
5.4. Sets optimum levels of remediation for historical actions?	Does not specifically address a procedure to determine clean-up levels, but maintains that remediation must be undertaken until levels are less than ARLs (DWAF, 1998b:9-4). Due to the conservative nature of these levels, and the fact that site specific conditions are not assessed, this can imply that clean-up must be more comprehensive than the natural background levels.	☹	Since the procedure deals mainly with the discharge of effluent into a resource, site-specific remediation is not addressed. It may, however, be necessary to assess and remediate the in-stream impact of a historical discharge, since settling of sediment on the riverbed may act as a long-term non-point source of pollution, and assessment and remediation is therefore a necessity.	☹

Table 10 (continued): Comparative evaluation of existing approaches against established criteria

Evaluation criterion	Minimum Requirements approach (ECA 73/1989)		PAEDI approach (Water Act 54/1956)	
6. Scientific determination of *de minimis* risk?	Threshold or *de minimis* risk is not addressed, but it could be argued that this is represented by 10% of the LC_{50} value (ARL)	☹	Threshold or *de minimis* risk is not addressed, but it could be argued that it is represented by the Target Water Quality Guideline (TWQG) value.	☹
6.1. Conservative threshold exposure levels?	The ARL can be regarded as a threshold level for setting regulatory intervention in motion, although the disposal of waste on land is the regulatory trigger.	😐	The TWQG values can be regarded as threshold levels for setting regulatory intervention in motion, although the General Effluent Standard is the regulatory trigger.	😐
Assessment approach and procedures				
7. Identifies hazards & exposures on the basis of *de minimis* risk?	Although both potential hazards resulting from waste sources, and exposure scenarios, are identified, the identification is not based on a *de minimis* risk.	☹	Although both potential hazards resulting from waste sources, and exposure scenarios, for the receiving environment are identified, the identification is not based on a *de minimis* risk.	☹
7.1. Identifies all potential sources of hazards?	Although all industrial waste is regarded as hazardous, all potential hazards are not identified, e.g. the hazards posed by the disposal of waste with high liquid content on land, and the hazards posed through pathways other than the aquatic pathway.	☹	The sources of hazards identified by this procedure are those stipulated in the definition of industrial effluent in the 1956 Water Act. Other potential hazards not covered by this definition are therefore not identified.	😐
7.2. Identifies vulnerable characteristics of the receiving environment?	The MRWDL specifies "fatal flaws" which identify certain characteristics of the receiving environment where waste disposal sites may not be located.	☺	The effluent standards (general and special) published in the Government Gazette specify catchments of concern, to which the special effluent standard and the special standard for phosphate apply for discharges.	☺
8. Integrates inputs from across scientific boundaries?	Since the focus is on the source, and general assumptions are made about the characteristics of the receiving environment, integration of different fields of science does not take place during the assessment.	☹	Since the characteristics of both the source and the receiving environment are taken into consideration during the assessment, and site-specific circumstances are used in the modelling of impacts, the assessment is made in an integrated manner.	☺
9. Both source and environment assessed in integrated manner?	Only the source is assessed, in order to determine the correct disposal site, but since the categorisation of disposal sites does not distinguish between different levels of protection, this leads to confusion.	☹	Characteristics of both the source and the receiving environment are taken into consideration during the assessment.	☺
10. Assessment of the total intrinsic hazard posed by the source?	Assessment is limited only to the toxicology of the individual chemical constituents, and the possibility of realisation of the hazard through the aquatic pathway. Other factors influencing the intrinsic hazard, such as liquid content, airborne pathway, etc. are not evaluated. Although the assessment focusses on the aquatic pathway, the hazard posed by dissolved salts of constituents (e.g. sulphate, sodium) are seldom assessed	☹	The different sources are identified and their impacts are quantified on the basis of their properties and characteristics and any other factors (DWAF, 1995:66)	☺
10.1. Hazard assessment categorises sources to prioritise regulatory intervention?	Sources of concern (presenting harm to human health and safety) are identified firstly by assessing a waste stream in terms of SABS Code 0228, and thereafter by placing the stream in a hazard group based on its EEC. However, since registration of waste generators is not yet compulsory, this assessment takes place in an ad hoc manner.	😐	Prioritisation of intervention is not addressed, and regulatory intervention takes place in an ad hoc manner.	☹

Table 10 (continued): Comparative evaluation of existing approaches against established criteria

Evaluation criterion	Minimum Requirements approach (ECA 73/1989)		PAEDI approach (Water Act 54/1956)	
10.2. Hazard assessment evaluates individual hazards, as well as cumulative impacts?	An attempt is made to assess cumulative impact through the calculation of total load for a specific constituent. This does not correctly estimate the actual cumulative impact since no waste load can be spread evenly over the total area of a site, and the cumulative impact of different constituents of a single waste stream is not assessed.	☹	The procedure is aimed mainly at point source management (DWAF, 1995:11), and does not assess the cumulative impact of different constituents in the same source or single constituents from various sources, although assimilative capacity determination takes cognisance of this, and non-point sources are addressed (DWAF, 1995:131-147).	☹
10.3. Hazard assessments during product, project, and service life cycles?	The total load calculation attempts to simulate the service life cycle of the site, but does not correctly estimate actual carrying capacity, since total load addresses only individual constituents and does not reflect site-specific conditions.	☹	The product life cycle is addressed by assessment of the mass balance of the source, and the use of raw materials and reagents to predict the composition of waste streams. However, impacts during project or service life cycles are not determined.	☹
11. Exposure assessment of specific characteristics of receiving environment?	Not taken into consideration, apart from the size of the disposal site, which is used in conflict with the principle of containment to mitigate against the effects of the disposal.	☹	Is addressed during the assessment by evaluation of hydrological characteristics, natural features, stream flows, baseline quality, etc. and classification of rivers	☺
11.1. Categorise environs to prioritise intervention?	Waste disposal sites are categorised, but categorisation is not directed at prioritisation of high risk (polluting) activities.	☹	Prioritisation is not addressed specifically, and regulatory intervention takes place in an ad hoc manner.	☹
12. Effect of risk-reduction and protection measures taken into consideration?	Although the MRWD requires the implementation of risk-reduction measures, the MRHW does not take cognisance, during assessment, of this implementation by the site manager. No incentive is therefore created to prefer factors beneficial to the environment, such as better site selection and buffer zones as well as superior site design over economic aspects. during selection or construction of a disposal site,	😐	Selecting optimum hydrological conditions for a new discharge action is addressed and taken into consideration in the assessment procedure, but other risk-reduction measures, e.g. the implementation of state of the art treatment plants, are not specifically addressed.	😐
12.1. Considers standard of design, operation, and maintenance?	Although a site may be well selected and engineered, poor operation can result in an increased risk of failure and contamination, but this is not taken into consideration during assessment.	☹	Although the hydrological conditions at the point of discharge may be favourable, or a treatment facility may be well designed, the standard of operation can be poor, resulting in the discharge of untreated effluent but this is not taken into consideration during the assessment.	☹
13. Does it estimate the risk?	The calculation of the EEC does not estimate the actual risk by comparing hazard and exposure assessments.	☹	The actual risk is not estimated on the basis of an evaluation of the hazard and exposure assessments.	☹
14. Different levels or tiers of assessments?	The approach does not entail different levels of assessment and investigation depending on the urgency of the decision, and is at best a prescribed semi-quantitative hazard assessment based on conservative assumptions.	☹	The approach allows different levels of investigation, each progressive tier requiring more detailed information, depending on the urgency of the decision and the amount of information required by the regulator to facilitate a decision or submitted by the applicant to support his application.	☺
14.1. Each assessment tier more detailed?	No. All phases of the total classification system have to be followed in order to arrive at a final outcome.	☹	Yes. The tiers depend on the quality of information provided, and whether a decision can be made at that point regarding the sustainability of the discharge.	☺
14.2. Quick qualitative determination under emergency conditions?	No, apart from a statement that all wastes are regarded as hazardous. When a hazardous site is not available under emergency conditions (kwaZulu-Natal situation 1997), a quick assessment of the best alternative disposal option is not possible.	☹	In certain circumstances, comparing the quality of the effluent with the specified effluent standards can be regarded as a qualitative assessment, although this is not based on the most conservative comparison, and will not provide a precautionary decision under emergency conditions.	😐

Table 10 (continued): Comparative evaluation of existing approaches against established criteria

Evaluation criterion	Minimum Requirements approach (ECA 73/1989)		PAEDI approach (Water Act 54/1956)	
14.3. Semi-quantitative determination according to prescribed calculation procedure?	The procedure of calculating the EEC and comparing it with the ARL can be described as a semi-quantitative determination of risk, but it is not adequate, since neither the risk of high liquid content in the source, nor environmental exposure, are determined.	☹	Contains no prescribed calculation procedure for the semi-quantitative assessment of hazards and exposure scenarios	☹
14.4. Quantitative determination using models, additional information, etc.?	The MRHW state that in some instances (e.g. rehabilitation) a detailed site-specific risk assessment should be conducted (DWAF, 1998b:7-3). This does not apply to the determination of the correct disposal site for a specific waste stream	☺	Makes provision for the use of models, simulations, etc in quantifying and predicting the effects of a discharge on water quality	☺
Decision-making considerations				
15. Compares the estimated risk with the acceptable risk?	Although the procedure involves comparing the EEC with the ARL, this does not constitute risk characterisation, since the calculation of the EEC does not constitute risk estimation.	☺	The procedure does not make provision for the characterisation of risk based on the comparison of estimated risk (resulting from hazard and exposure assessments) with acceptable risk.	☹
15.1. BPEO for different environmental media?	Since there is no true risk estimation, the actual risks of different media cannot be compared to determine the BPEO.	☹	Since there is no estimation of actual risk, the actual risks of different environmental media cannot be compared to determine the BPEO.	☹
15.2. BPEO for different pre-treatment methods?	Since there is no risk estimation, the actual risks of different treatment methods cannot be compared to determine the BPEO.	☹	Since there is no risk estimation, the actual risks of different treatment methods cannot be compared to determine the BPEO.	☹
15.3. BPEO for disposal/ discharge methods?	Since there is no risk estimation, the actual risks of disposal vs. those of discharge cannot be compared to determine the BPEO.	☹	Since there is no risk estimation, the actual risks of disposal vs. those of discharge cannot be compared to determine the BPEO.	☹
15.4. BPEO for remediation and rehabilitation?	The MRHW (DWAF, 1998b:7-3) state that the choice and strategy for clean-up and remediation should be based on a detailed risk assessment that includes hazard evaluation, exposure assessment and risk characterisation, and that clean-up levels must be set at the ARL (10% of the LC_{50} value)	☺	Since there is no risk estimation, the BPEO for implementing remediation measures cannot easily be determined.	☹
16. BPEO = most favourable comparison?	Since acceptable risk cannot be effectively compared with estimated risk, the BPEO cannot be determined.	☹	Since acceptable risk cannot be effectively compared with estimated risk, the BPEO cannot be determined.	☹
17. Burden of proof?	Costs for analysis of samples, collection of information, and calculation of EEC for account of generator or waste site operator.	☺	Costs for analysis of samples, collection of information, and effluent discharge investigation for the account of the applicant.	☺
18. Judgement used by regulator for uncertainty?	The procedure does not make provision for the use of justified judgement by the regulator in the face of uncertainty.	☹	Judgement is used when uncertainties arise, and the rule applied is to err on the safe side (DWAF, 1995:192).	☺
18.1. Informed decision based on reasonable & realistic level of detail?	The procedure does not make provisions for different levels of investigation, which means that small generators have to conduct the same expensive and detailed investigations as those generators with high waste volumes.	☹	Although provision is made for different levels of investigation, the lack of a prescribed for semi-quantitative determination of estimated risk may result in a too-detailed study not warranted by the significance of the impact.	☺
18.2. Each tier of assessment reduces judgement?	Only one tier of investigation, namely a detailed evaluation that does not make provision for judgement.	☹	The more information provided, the less the need for the use of judgement, since the less the uncertainty. However, since the level of judgement is not always quantified, this could lead to disputes and public mistrust.	☺
19. Verification of information provided?	Procedure does not specify that information is to be verified by the responsible authority, although this does take place in practice.	☹	Specifically provided for during the assessment of the application, where information provided is evaluated in order to determine the uncertainties associated with the decision.	☺

Table 10 (continued): Comparative evaluation of existing approaches against established criteria

Evaluation criterion	Minimum Requirements approach (ECA 73/1989)		PAEDI approach (Water Act 54/1956)	
20. Prioritisation of regulatory involvement?	This is not addressed. Regulatory involvement takes place in an ad hoc manner, and is mostly dependant on historical involvement or the activity's being brought to the attention of the regulator by either the site operator or the affected sector of the public.	☹	This is not addressed. Regulatory involvement takes place in an ad hoc manner, and is mostly dependant on historical involvement or the activity's being brought to the attention of the regulator by the applicant, or the affected sector of the public or concerned individuals.	☹
21. Indication of appropriate resource economics?	Since the NWA was promulgated after the establishment of the approach, no provision is made for the determination of the appropriate resource economics.	☹	Since the NWA was promulgated after the establishment of the approach, no provision is made for the determination of the appropriate resource economics.	☹
22. Integrates scientific, socio-economic & political considerations?	This integration takes place only during site selection, where economic, environmental and public acceptance criteria are used to compare different candidate sites.	😐	Socio-economic, political and scientific considerations are integrated during the application process to formulate water quality management objectives and strategies.	☺
23. Public involvement in the decision-making process?	The public is involved in site selection, permitting of existing sites, determining closure objectives for rehabilitation of sites, and monitoring committees for some operating sites.	☺	The public is involved in the application process, specifically in establishing receiving water quality objectives, assessing the application, establishing requirements for the authorisation and ensuring compliance.	☺
23.1. Perceptions?	Public perceptions regarding risk are not specifically addressed	☹	Public perceptions regarding risk are not specifically addressed	☹
23.2. Understandable information?	Information is not always made available in an understandable manner, and the Minimum Requirements are written in a highly technical language, although a "Popular version" was published.	😐	Information is not always made available in an understandable manner, PAEDI is written in highly-technical language, and the uses of the different models are not explained in layman's terms.	☹
23.3. Uses clear terminology to distinguish between different risk situations?	The terminology used is not clear, and can create confusion. The same term (H:H) is used to described a landfill site designed to the highest standards of engineering and a contaminated historical site. Also, the same term (hazardous waste) applies to explosive waste and ash waste containing only manganese, which holds little risk of harm for humans.	☹	The approach does not really ascribe terms to different situations, probably since effluent is not regarded as a serious threat to human safety and health, although it could be regarded as such under certain circumstances. Also, it does not distinguish between acceptable and unacceptable discharge situations.	😐
General considerations				
24. Framework itself continuously improved?	The Minimum Requirements are regarded as "living documents", and the 1994 edition was updated in the 1998 edition.	☺	The 1995 edition of PAEDI was the first publication of this approach, which will probably be updated to incorporate the requirements of the NWA.	😐
24.1. Re-evaluation of semi-quantitative assumptions?	No continual re-evaluation of the assumptions contained in the prescribed semi-quantitative assessment (calculation of EEC) have been conducted to date.	☹	No, does not contain semi-quantitative assessment	☹
25. Re-assessment of the actual impact based on monitoring results?	The actual impact of the decision once it is implemented, as reflected by monitoring results, is not taken into consideration in any re-assessment of the decision.	☹	The actual impact of the decision as reflected by monitoring results is taken into consideration in the periodical re-evaluation of the decision to allow the discharge.	☺

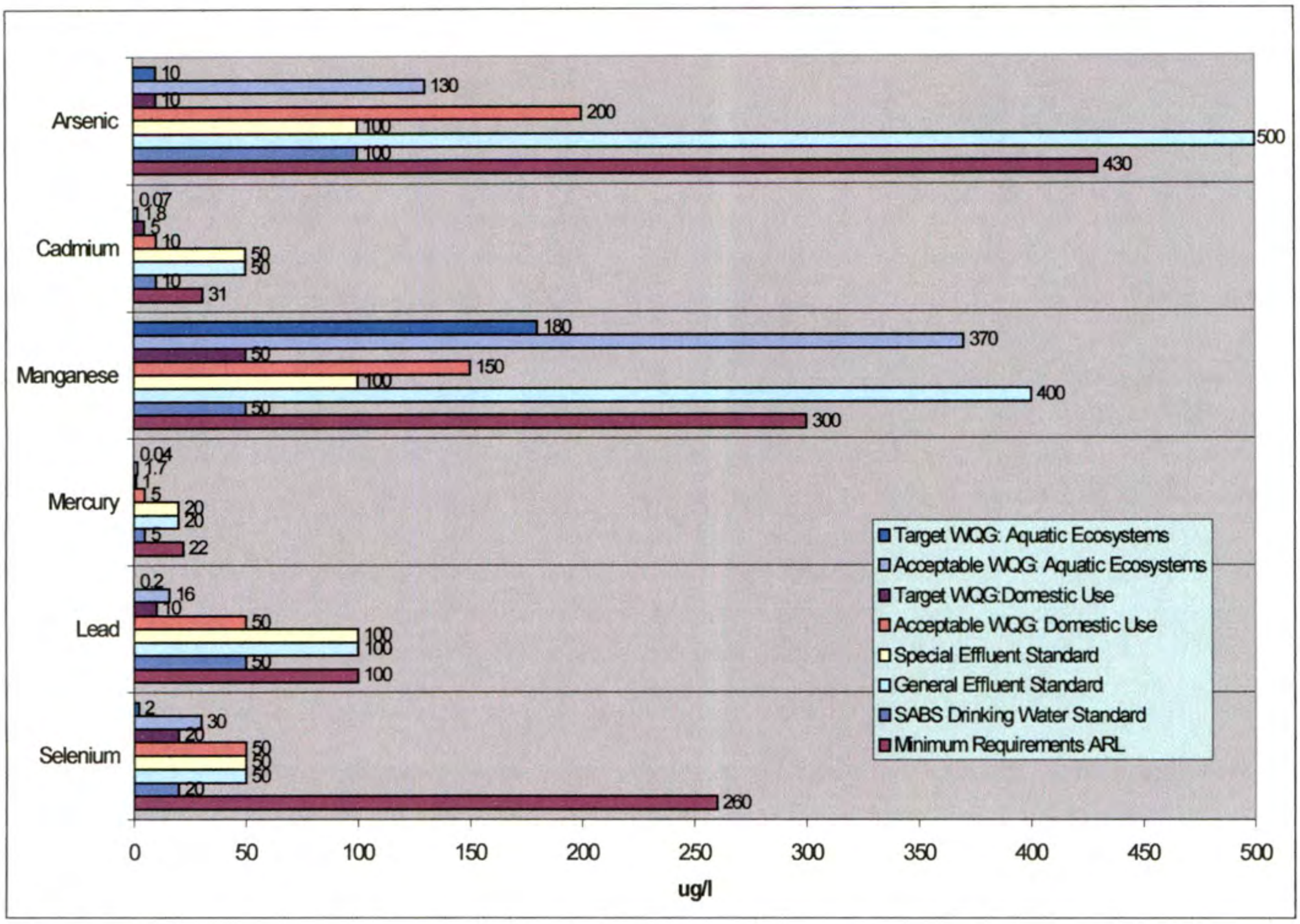

Figure 17: Comparison between regulatory values related to the water resource (lower scale)

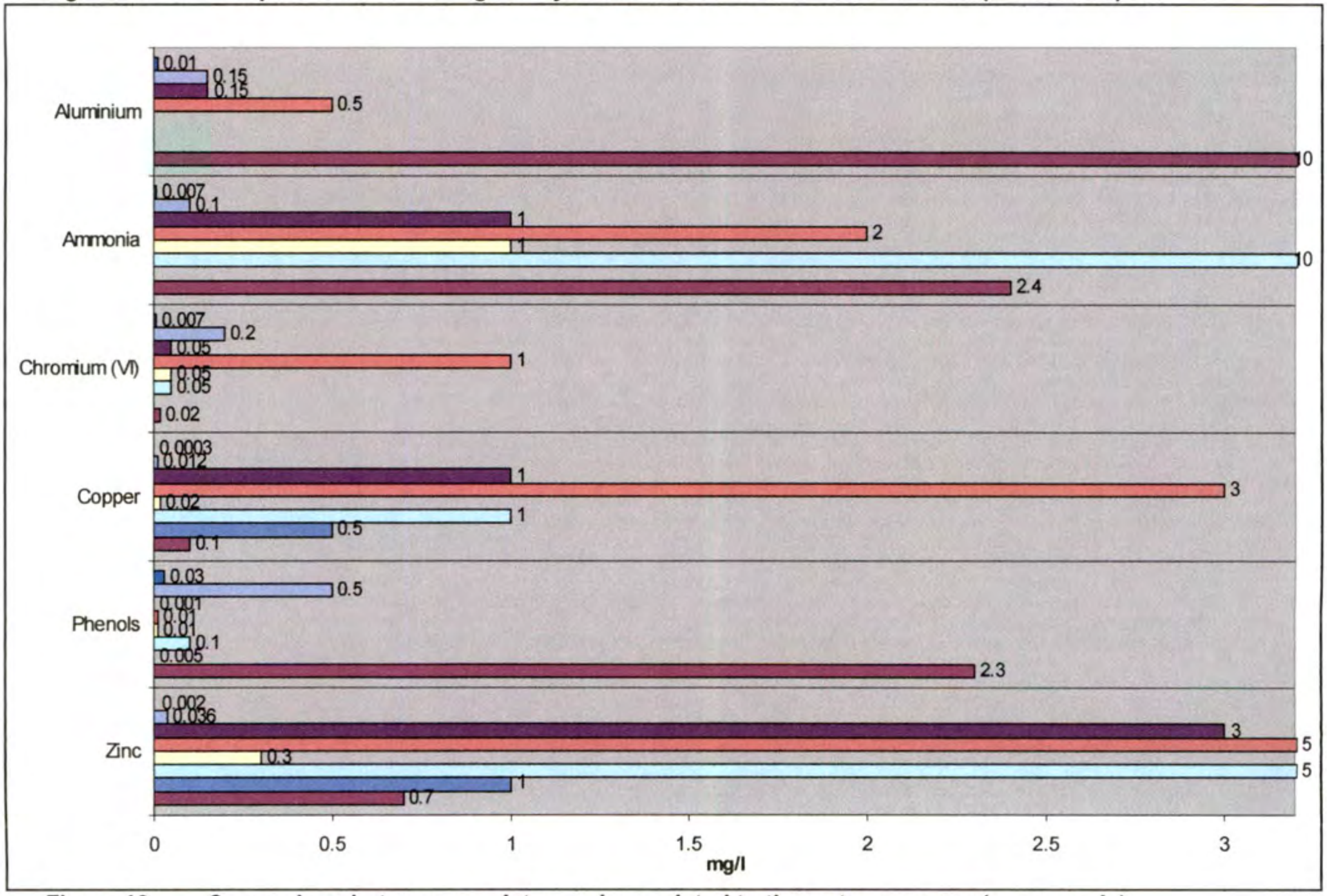

Figure 18: Comparison between regulatory values related to the water resource (upper scale)

4.5.2 RESULTS OF THE LACK OF AN INTEGRATED APPROACH

On the basis of the evaluation in Table 10 above, it is clear that although both approaches address certain elements of sustainability, the following are considered the main disadvantages:

1. The most important is the lack of a uniform acceptable risk determined at political level. This results in the specification in the documentation of various different threshold and optimum use levels, although all are applicable to the indivisible water resource. Some of these values are listed in Table 11 below, and a schematic comparison between the values is depicted in Figure 17 for constituents with lower concentrations and in Figure 18 (higher concentrations).

Table 11: Some regulatory values applicable to the water resource

Constituent	Arsenic	Cadmium	Manganese	Mercury	Lead	Selenium
Unit	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
Target WQG: Aquatic Ecosystems	10	0.07	180	0.04	0.2	2
Acceptable WQG: Aquatic Ecosystems	130	1.8	370	1.7	16	30
Target WQG: Domestic Use	10	5	50	1	10	20
Acceptable WQG: Domestic Use	200	10	150	5	50	50
General Effluent Standard	500	50	400	20	100	50
Special Effluent Standard	100	50	100	20	100	50
SABS Drinking Water Standard	100	10	50	5	50	20
Minimum Requirements ARL	430	31	300	22	100	260
Minimum Requirements Hazard Rating	2	1	2	1	2	2
Constituent	Aluminium	Ammonia	Chromium (VI)	Copper	Phenols	Zinc
Unit	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Target WQG: Aquatic Ecosystems	0.01	0.007	0.007	0.0003	0.03	0.002
Acceptable WQG: Aquatic Ecosystems	0.15	0.1	0.2	0.012	0.5	0.036
Target WQG: Domestic Use	0.15	1	0.05	1	0.001	3
Acceptable WQG: Domestic Use	0.5	2	1	3	0.01	5
General Effluent Standard	-	10	0.05	1	0.1	5
Special Effluent Standard	-	1	0.05	0.02	0.01	0.3
SABS Drinking Water Standard	-	-	-	0.5	0.005	1
Minimum Requirements ARL	10	2.4	0.02	0.1	2.3	0.7
Minimum Requirements Hazard Rating	3	1	1	2	3	2

From these comparisons, it is evident that there is no clear cut-off point between sustainable use and pollution. For example, the TWQG for domestic use for zinc is 3mg/l, and substances containing this amount of zinc can be discharged into a water resource. However, the MRHW specify that a substance containing zinc at a concentration of more than 0.7 mg/l must be disposed of in a hazardous waste disposal site equipped with a two-metre thick protective lining system. Another example is aluminium, where the AWQG for aquatic ecosystems are set at 0.15 mg/l, although the element is found naturally at concentrations of up to about 0.5 mg/l owing to its incidence in geological formations characteristic of many parts of the country. There are many similar examples, including those specified at levels lower than the detection limits of most laboratories. Ragas and Leuven (1999:185) state that such different emission limits specified under comparable conditions may be regarded as unequal treatment of waste generators (unjust administrative action). The point is, however, that these discrepancies are the result of the lack of an integrated approach based on a politically-determined acceptable risk, from which optimum use and threshold levels can be deduced.

2. The second main disadvantage is that neither of the two approaches leads, from a holistic perspective, to the implementation of the BPEO for the medium or method of disposal or discharge. It could be stated that this shortcoming is owing to the fact that the assessment is not done in an integrated manner, based on a strong hierarchy of decision-making framework aimed at identifying the BPEO. The result of this is that the wrong disposal option is often implemented, which causes secondary problems at the point of disposal. One of the results of this lack of integration is illustrated in Figure 19 below, which shows a waste disposal site where the operators have to deal with approximately 200 000 m^3 of leachate, which arose as a result of the incorrect disposal over a period of five years of too much liquid waste at the site.

Figure 19: Large volume of leachate stored at waste site due to incorrect option for management of liquid waste

3. The third important shortcoming is the lack of an assessment procedure that is risk based, and that contains a prescribed semi-quantitative determination of estimated risk. Although an attempt at establishing such a mechanism has been made with the introduction of the EEC calculation in the MRHW, this calculation does not reflect risk estimation accurately or holistically.

4.6 SUMMARY

The mere fact that two approaches exist indicates the need for integration, especially since the different optimum use levels create confusion with regard to when an action will cause pollution, and the BPEO cannot be determined from a holistic perspective. However, both procedures have certain suitable aspects, such as the public participation procedures throughout the service life cycle of the activity, the fact that they contain certain elements of risk determination, and that they are aimed at pollution prevention. These aspects can be utilised in the establishment of an integrated approach, which should not be a reinvention of the wheel, but rather a marriage between the two existing approaches in the context of the requirements of the NWA. The next chapter aims to suggest the framework within which such an integrated approach can be developed.

CHAPTER 5: PROPOSED HARMONISED REGULATORY FRAMEWORK FOR SOUTH AFRICA

5.1 INTRODUCTION

As governments internationally started to become aware of the impact of industrialisation on the environment, their various sectors and agencies responded with concern, but in an unco-ordinated manner, in establishing regulations to control such impacts (Kamrin, 1997:1). This resulted in different legislation, and different approaches and procedures, aimed at managing the same impacts, as well as in different levels of acceptability of exposure. The fragmentation of these responses is evident in the proliferation of medium- and issue specific legislation and inconsistencies in procedural approaches, a phenomenon that is not limited to South Africa. Recently, efforts have begun to be made, especially in the United States and Europe, to harmonise these approaches in order to reduce inconsistencies and provide an altogether more integrated and co-ordinated approach to determining the risks associated with waste disposal and discharge, as well as other environmental emissions (Kamrin, 1997:8). These efforts are collectively known as **risk harmonisation**. From Figure 12 (page 48), it is evident that certain preparatory actions should be taken to facilitate the implementation of a harmonised risk analysis framework aimed at the management of potential risks resulting from waste disposal or discharge actions. The two approaches described and evaluated in chapter 4 both contain some aspects of risk analysis that could be incorporated into this framework, provided that cognisance is taken of the provisions of the newly-promulgated NWA. In order to arrive at such a harmonised framework, it is suggested that the responsible national authority (DWAF) implement the following actions:

1. Facilitate a political decision on **acceptable risk** to enable decision-making regarding the BPEO. Once the acceptable risk has been determined, an integrated set of **regulatory criteria** for optimum use and *de minimis* levels can be developed for different exposure scenarios, and water quality standards for waste disposal or discharge can be established.
2. Develop a **harmonised hierarchy for decision-making** in terms of the NWA, that includes a risk assessment approach, which is aimed at determining the BPEO according to comparison of the estimated risk with the acceptable risk during risk characterisation.
3. Develop the **risk assessment approach**, where hazard identification can be based on the regulatory criteria, and which involves a **prescribed procedure for a semi-quantitative** risk assessment.

In this Chapter, some suggestions are made towards the establishment of such a harmonised framework. Based on the harmonised hierarchy of decision-making, which incorporates an assessment approach, some suggestions are made towards the formulation of a prescribed semi-quantitative procedure within the suggested risk assessment approach.

5.2 ACCEPTABLE RISK AND REGULATORY CRITERIA

In terms of the sustainable discharge or disposal of waste, the most important fundamental principle on which the NWA is based is **Principle 7**, which states that: "The objective of managing the quantity, quality and reliability of the nation's water resources is to achieve **optimum**, long term, environmentally sustainable social and economic benefit for society from **their use**" (DWAF, 1997a:35). This concept is in accordance with those introduced in Figure 3 (see page 17). Optimum use of the water resource for waste disposal or discharge purposes will constitute a discharge or disposal at a **level where the risk is acceptable** (i.e. at or below the level Q).

5.2.1 ACCEPTABLE RISK

The concept of optimum use is based on the **carrying capacity principle**. The Policy on which the NWA is based (see section 3.4) states that bodies of water can absorb only a certain quantity of contaminants without ill-effect (DWAF, 1997a:22), and that if the use of water resources remains within their capacity to recover, use at this level can probably be sustained in the long term. This implies that the disposal of waste or discharge of water containing waste can or may be done in a manner that constitutes a sustainable use of the water resource, and that will therefore not be regarded as pollution, provided that the impact is at or below a certain level.

The determination of acceptable risk should be a decision made at a political level, albeit based on scientific input with regard to carrying capacity. As a rule of thumb, incremental risks of between 10^{-4} and 10^{-7} are generally perceived as acceptable levels for the protection of both human health and environmental integrity, with 10^{-6} as the point of departure (Asante-Duah, 1993:106). Chronic risks to human health are more substantial than ecological risks in most situations, and risk-reduction measures taken to prevent risks to human health are often sufficient to mitigate potential ecological risks at the same time (Asante-Duah, 1996:152). In those situations where particularly sensitive environments or species may be exposed, they could be listed as non-value based criteria.

Therefore, on the basis of international practice, it is suggested that for non-carcinogenic contaminants a risk of the incidence of death in the human population of 1 in 10^{-6} should be considered acceptable in South Africa for individual and cumulative disposal or discharge actions, determined on a site- or catchment-specific basis. Owing to the fact that people may be exposed to the same constituents from sources unrelated to a specific site or action, the acceptable carcinogenic risk should be $< 10^{-6}$ (Asante-Duah, 1993:106). The same factor (i.e. 1 in 10^{-6} incidence of human mortality) should be used for situations where public safety is at risk.

5.2.2 REGULATORY CRITERIA FOR THE CATEGORISATION OF WASTE DISPOSAL OR DISCHARGE ACTIONS

Once a political decision regarding acceptable risk has been facilitated, a *de minimis* risk should be established scientifically. On the basis of these, a set of regulatory criteria for optimum and *de minimis* exposure can be developed for different categories of chemical substances and different environmental exposure scenarios. These regulatory criteria could be either non-value-based, involving situations or conditions, or value-based, involving concentrations (for example environmental standards), distances, etc., and can be used to establish risk-categories of waste disposal actions, facilities and media according to their actual or potential aggregate risk. The following regulatory criteria should therefore be developed:

- A set of regulatory criteria for the categorisation of waste streams according to human safety and health related hazards (also known as a waste classification system) based on the intrinsic hazard associated with the waste itself; and
- A set of regulatory criteria for the categorisation of waste disposal or discharge actions or facilities, which should be determined specifically for various exposure scenarios for the relevant environmental media involved in land-based disposal and disposal into the resource.

These regulatory criteria or levels for optimum and *de minimis* exposure should be applicable countrywide, regardless of where the action will be conducted, and should result in an integrated database of values and prescriptions. They could be based on the physical or chemical nature of the waste, the origin of the waste, or the characteristics of the (potential) receiving environment, such as resource class, management (or resource quality) objectives, and existing or proposed environmental protection considerations. These regulatory criteria can then be used during both the hazard identification phase of the risk assessment, and during a qualitative risk assessment. Special care should be taken with terminology used in the systems that are developed, in order to address potential problems with risk perception.

5.2.2.1 NON-VALUE BASED REGULATORY CRITERIA

Non-value based criteria could be based on the characteristics of the environment as well as the nature of the waste. Some of these criteria have already been developed, as indicated below, but should be revisited to address possible inconsistencies with the specified acceptable risk.

5.2.2.1.1 Regulatory Criteria for Waste Characteristics

Non-value-based prescriptions could be easily established for the wastes that hold a risk to public safety or health and for which the risk of harm or hazard is known, as depicted in Figure 8 (page 31). The MRHW does currently contain some non-value-based criteria that could be used for waste characterisation. These should, however, be revisited in order to address discrepancies, and to provide for the entire waste stream in terms of the NWA definition of waste. It is suggested that the non-value-based requirements for waste characteristics could include the characteristics listed in Table 12 below in progressive order of reducing risk:

Table 12: Non-value-based criteria for waste characteristics

Description	Non-value-based criteria
1. ***Highly hazardous*** *waste*	*Where the nature, and physical or chemical properties of any waste other than domestic waste is unknown, it will be regarded as being of the highest hazard category, and must be handled accordingly until such time as these properties and their associated risks have been determined.*
2. ***Perilous waste***	*Waste posing a serious risk of harm to human safety will be regarded as **Perilous**, and may **never** be disposed of on land or discharged into a resource, but must be **destroyed**, according to the appropriate legislation where applicable.*
3. ***Dangerous*** *waste*	*Waste posing an **acute** risk to human health owing to possible poisoning, infection, disease or cancer, will be considered **Dangerous**, and may **never** be disposed of on land or discharged into a resource, but must be either **destroyed or isolated** in absolute containment, according to the appropriate legislation where applicable.*
4. ***Precarious*** *waste*	*Waste posing a **chronic risk** to human health owing to its nature or chemical characteristics, will be considered **Precarious**, and may **never** be discharged into a water resource, but may be disposed of on land (with or without pre-treatment) in **high-protection waste disposal facilities**, following a **risk assessment** and according to the applicable legislation.*
5. ***Intermediate*** *waste*	*Waste posing an **uncertain**, unknown or suspected **chronic risk** to human health and/or environmental integrity owing to its chemical characteristics, will be considered **Intermediate** and, following a **risk assessment** to determine the correct disposal option, may be disposed of on land in **moderate-protection waste disposal facilities** or **discharged** into a water resource on the basis on the protection offered by the disposal action, and according to the applicable legislation.*
6. *Domestic waste*	*Waste containing solid or semi-solid material originating from households may **never** be discharged into a water resource, but **must** be disposed of in any **permitted low-protection** disposal site, which was designed at least for domestic waste according to climatic calculations and according to the applicable legislation*
7. *Harmless low moisture content waste*	*Industrial waste with low moisture-content and a **risk assessment** indicating that its estimated risk < de minimis risk may **never** be discharged into a water resource, but **must** be disposed of in any **permitted** low protection disposal site designed at least according to climatic calculations and according to the applicable legislation*
8. *Harmless high moisture content waste*	*Industrial waste with high moisture-content and a **risk assessment** indicating that its estimated risk < de minimis risk may **never** be disposed on land in an disposal site but **must** be discharged into a water resource, and according to the applicable legislation*

A further categorisation and an explanation of the characteristics of each of these categories is contained in **Annexure A**.

5.2.2.1.2 Regulatory Criteria for Environmental Characteristics

Non-value based-criteria for environmental characteristics could include requirements such as the "fatal flaws" that are already listed in the Minimum Requirements (DWAF, 1998c:4-5), or the document "Procedures to assess effluent discharge impacts" (DWAF, 1995:43), for example:

- A waste disposal site may not be located in the 1 in 50 year flood line; and
- A waste disposal site may not be located in an ecologically or historically sensitive area.

The existing non-value-based criteria for environmental characteristics should be expanded upon to allow for the resource classification system currently being developed in terms of s12 of the NWA for resource-directed measures, which may lead to criteria such as:

- Lists of sensitive catchment areas which may not be used for waste discharge or disposal; and
- Lists of sensitive species and the catchment areas in which they occur.

A categorisation of waste disposal and discharge activities is contained in **Annexure B**.

5.2.2.2 *VALUE BASED REGULATORY CRITERIA*

Value-based regulatory criteria (often referred to as levels or concentrations) for optimum use can be used to set resource quality objectives, while *de minimis* criteria can be used to establish the threshold concentration level where regulatory involvement becomes necessary. Such regulatory criteria for chemical constituents (also known as regulatory doses, reference doses (RfD) or acceptable daily intakes (ADI)), can be determined on the basis of internationally-accepted procedures and guidelines, using, for example, the following equations (Asante-Duah, 1993:95):

$$\text{Regulatory Optimum Exposure Level (ROEL)} = \frac{\text{Acceptable Environmental Level (e.g. NOAEL)}}{\text{Uncertainty Factor (UF) x Modification Factor (MF)}}$$

and

$$\text{Regulatory De Minimis Exposure Level (RDMEL)} = \frac{\text{De Minimis Environmental Level (e.g. NOEL)}}{\text{Uncertainty Factor (UF) x Modification Factor (MF)}}$$

The Uncertainty Factor (UF) (also safety factor) and Modification Factor (MF) used in calculating the specific regulatory level reflect scientific judgement regarding the data used to estimate the level, and are used to offset uncertainties associated with extrapolation of data. **Uncertainty Factors** generally consist of multiples of 10, each factor representing a specific area of uncertainty inherent to the available data. For example, a factor of 10 may be introduced to account for the possible differences in responses between humans and animals in exposure studies. A second factor of 10 may be introduced to account for the variations in susceptibility of individuals in the human population. The resultant factor of 100 has been judged to be appropriate for many chemicals (Asante-Duah, 1993:95). For other chemicals, with less complete databases, an additional factor of 10 may be judged to be appropriate, leading to a UF of 1000. For chemicals for which responses in sensitive humans have been well studied (e.g. fluoride and its effect on human teeth), a UF of as little as 1 may be selected (Dourson and Stara, in Asante-Duah, 1993:95).

A **Modification factor** is determined by professional judgement, and is an additional UF that is greater than 0 and less than or equal to 10. The magnitude of the MF depends on professional assessment of the scientific uncertainties of the study and database with which the NOAEL or NOEL value was determined, which were not covered in the determination of the UF. Examples could include the completeness of the overall database and the number of species tested. The default MF is 1. Asante-Duah (1993:95) outlines some guidelines to be used in the determination of UF and MF values when deriving regulatory levels.

These levels are particularly useful in the hazard identification phase of the risk assessment, and can also be used with great effect in the semi-quantitative determination of risk, especially during risk characterisation. In order to facilitate the use of these criteria during a qualitative risk assessment, they should be converted to standards.

5.2.3 ESTABLISHMENT OF WATER QUALITY STANDARDS

The NWA requires that source-directed measures, such as **setting standards** for waste discharges, establishing best management practice guidelines etc., be developed to manage the disposal or discharge itself at the source. Asante-Duah (1993:95) gives some examples of the determination of standards for different exposure routes. The regulatory level discussed in the previous section should be set at the level determined for the exposure route that gives the most stringent value. This level must then be converted to a concentration in the appropriate medium of exposure, namely water (in the case of this study). For example, such a conversion of an ingestion exposure to a corresponding concentration in water can be calculated for optimum use (Asante-Duah, 1993:98) on the basis of the ROEL as follows:

$$\textit{Standard concentration in water (mg/l)} = \frac{\textit{Oral ROEL (mg/kg/day) x body weight (kg)}}{\textit{Ingestion rate (litres/day)}}$$

And for threshold exposure, on the basis of the RDMEL:

$$\textit{Standard concentration in water (mg/l)} = \frac{\textit{Oral RDMEL (mg/kg/day) x body weight (kg)}}{\textit{Ingestion rate (litres/day)}}$$

In the interim, while these integrated criteria are being determined, it is suggested that the existing target water quality guidelines for domestic use be used as ROEL standard criteria, and that target water quality guidelines for aquatic ecosystems be used as RDMEL standard criteria. These values should be updated as soon as the acceptable risk has been determined, albeit based on scientific input regarding carrying capacity, but at a political level.

5.3 PROPOSED DECISION-MAKING HIERARCHY

Decision-making regarding an application for allocation of a water use such as disposing of or discharging waste into a water resource, or in a manner that may impact on a water resource, will involve the determination of whether such disposal or discharge will constitute an optimum use, i.e. whether it will be sustainable. This means that the different *legal mechanisms* available in the NWA for regulating a water use (general authorisation, licensing, etc) should be incorporated into a hierarchy for decision-making. Water use as defined in the NWA will only be authorised if it is beneficial to the public interest, i.e. an "optimum use" (DWAF, 1997a:12). If not, it will be considered a "polluting action" which must be remedied.

The definition of waste in the NWA includes all types of waste, and all waste disposal actions (whether they be on land, into a water resource, or in any other manner that may impact on the water resource) can be regarded either as a non-consumptive use of water, or as causing pollution. As indicated in section 3.4, water uses are essentially controlled through a tiered authorisation system. The tiered authorisation mechanism contained in the NWA requires that decision-making be structured in such a way as to determine which type of authorisation if any, will be applicable for a specific action. Based on this, a proposed hierarchy for decision-making regarding disposal or discharge actions is outlined in Figure 20:

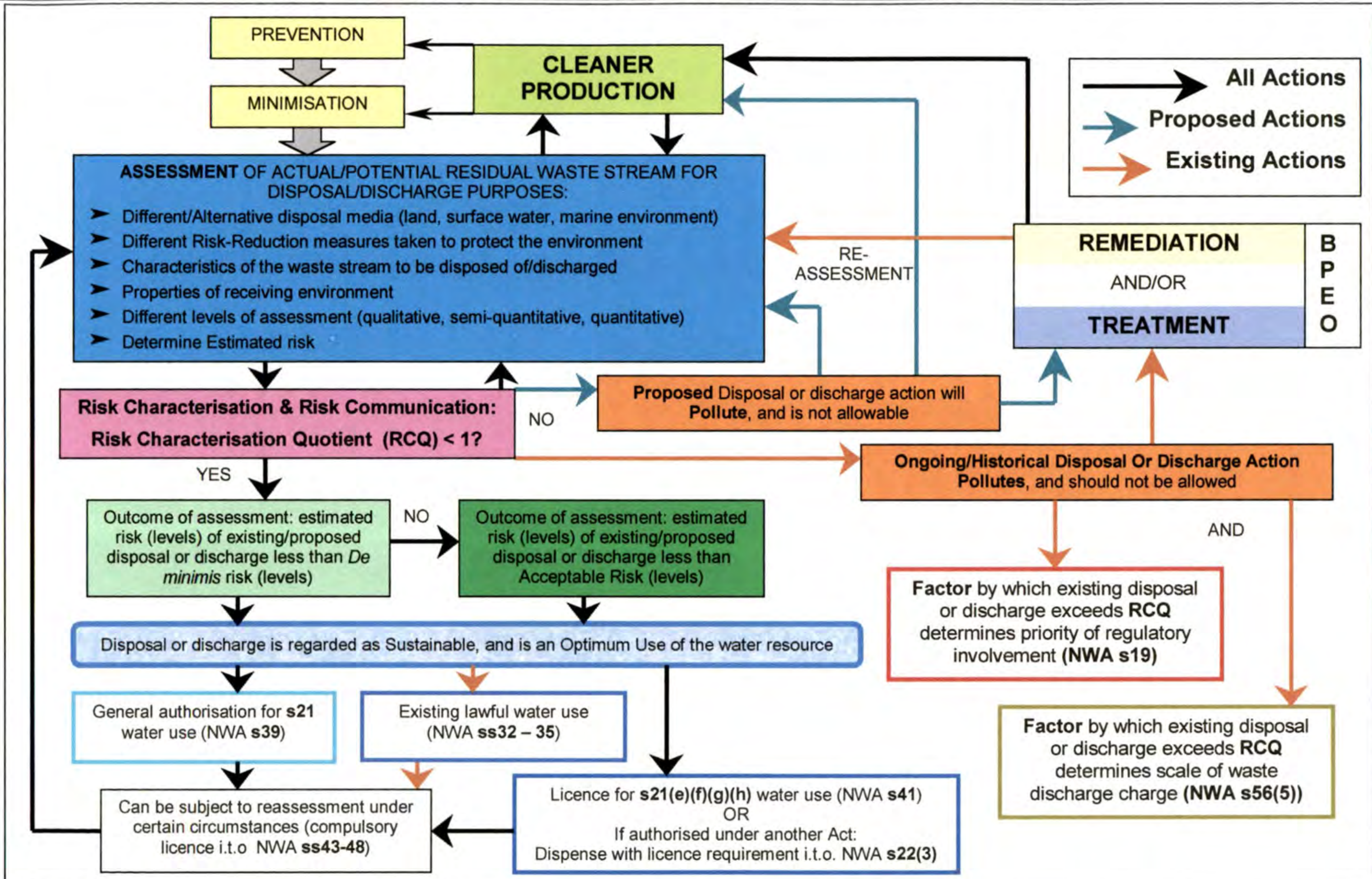

Figure 20: Proposed Hierarchy of Decision-making for intended, existing and historical disposal or discharge actions

A water use could be authorised as follows:

- a **general** authorisation issued in terms of s39 of the NWA;
- a **licence** issued in terms of s41 of the NWA;
- a **declaration** of a water use as an ***existing lawful use*** as defined in s32 of the NWA;
- a **dispensed** with a licence requirement under s 22(3) by the responsible authority; or
- a **compulsory** license subject to the provisions of s43 of the NWA.

Any water use which is not authorised, or which is not an optimum use will be considered a detrimental use that constitutes pollution. An application for an authorisation (licence) must be made in the form, contain the information, and be accompanied by the licence fee determined by the responsible authority (s41), and to the extent that it is reasonable, the applicant may be required to provide specific or additional information pertaining to the (proposed) use. **An assessment** of the likely effect of the use on the resource quality must be made by the applicant on the basis of the information provided, and an independent review of such an assessment may be required. This implies that, depending on the extent of the information required, the assessment can be made qualitatively, semi-quantitatively, or quantitatively. The assessment must, however, indicate whether the water use will be detrimental to the environment, or whether it will constitute an optimum or sustainable use of the resource. Lastly, the responsible authority must keep a record of his decision and must be able to give a reason for that decision (s42). This forms the background for a harmonised decision-making framework, and a discussion of the proposed hierarchy for decision-making is contained in the following sections.

5.3.1 CLEANER PRODUCTION

Pollution prevention and waste minimisation have been discussed in section 2.4.1, and are incorporated into the hierarchy for decision-making as its first priority. The applicant must therefore be able to demonstrate that cleaner production alternatives have been investigated, and the outcome of the assessment should also alert role-players to possibilities in this regard.

5.3.2 ASSESSMENT

As is clear from Figure 12 (page 48), the decision that has to be made is influenced by various factors, but the most important component of the decision-making hierarchy is the scientific outcome of the risk assessment. The **assessment** of the disposal or discharge action will determine whether such an action will constitute a sustainable (optimum/beneficial) use, or pollution of the water resource on the basis of the characteristics of the waste (dose) and the environmental conditions (exposure). Asante-Duah (1993:112) states that these factors can be analysed with different levels of detail, ranging from qualitative through semi-quantitative to quantitative analysis, depending on the circumstances.

5.3.2.1 LEVELS OF ASSESSMENT

The assessment procedure must therefore make provision for different tiers of investigation, in order to facilitate quick decisions in some instances, (e,g, emergency situations such as accidental spills), semi-quantitative assessments according to prescribed procedures, as well as for detailed quantitative assessments where use can be made of models to determine hazards, exposures, and protection factors. As required in terms of the NWA, in some instances the initial information provided will be sufficient to facilitate a decision. However, if the initial information is insufficient to facilitate a decision, the responsible authority can require additional information before making a decision. In other instances, the applicant may not be satisfied with the initial decision, and can then provide information based on a more detailed investigation. In instances where large sums of money will have to be spent in order to remedy the situation, it will be worthwhile to conduct a detailed quantitative investigation before deciding on the most cost-effective option for rehabilitation or treatment. The more quantitative the investigation, the less the level of uncertainty. When regulatory criteria have been established on the basis of an acceptable risk, it will be possible to assess the potential hazards and risks associated with a specific action. In order to conduct such assessment, the procedure to be followed should be clearly outlined. An appropriate a tiered investigation mechanism is illustrated, and the interrelationship between assessment, risk characterisation and decision-making is outlined, in Figure 21 below (based on Pedersen *et al.*, 1995:12, and DWAF 1995:30).

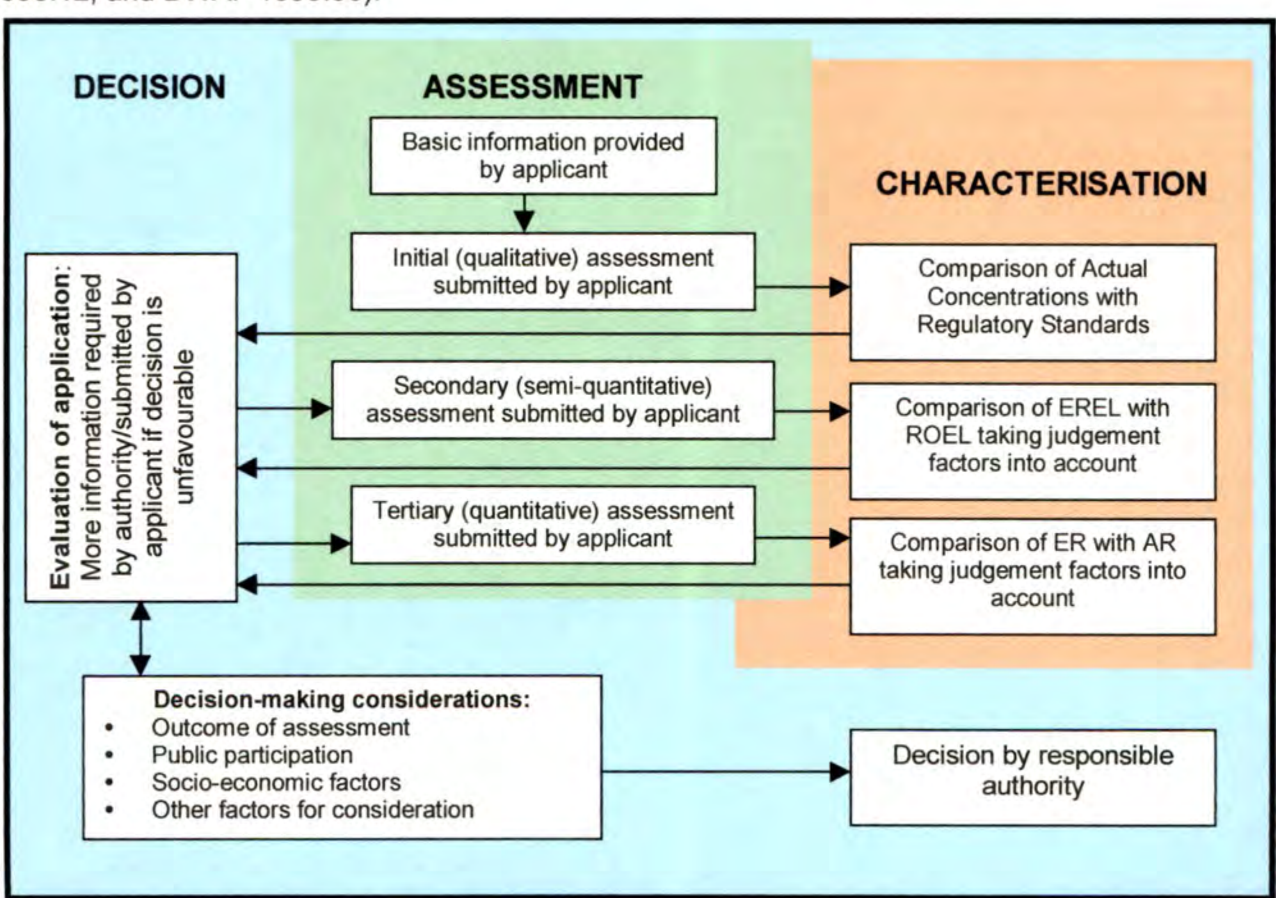

Figure 21: Tiered investigation mechanism showing interrelationship between Assessment, Risk Characterisation, and Decision-making

The procedures for each tier of assessment should, however, be the same, in order to facilitate an integrated decision regarding the BPEO to be implemented. The process of balancing social and economic benefits and determining environmental objectives should involve those affected in weighing up the **options** on an **informed** basis (DWAF, 1997a:13). The assessment approach itself should address all types of waste and take cognisance of the characteristics of the waste and the site-specific environmental conditions, and all possible mediums of disposal, such as land, fresh water and the marine environment should be considered. Both source- and resource directed measures taken to protect the environment must therefore be taken into consideration during the assessment.

5.3.2.2 SOURCE DIRECTED MEASURES

Principle 20 on which the NWA is based states that "The conditions upon which authorisation to use water is granted shall take into consideration the investment made by the user in developing infrastructure to be able to use the water". This implies that the measures taken by the user at source to protect the resource must be taken into account to determine whether such use is indeed sustainable. Furthermore, where existing uses are not at an optimum level, programmes or measures for adequate corrective action or remediation must be considered for implementation. These measures are referred to as ***source-directed*** measures aimed to control actions involving the use of water, in order to achieve resource protection. The principle applied is that discharges must be controlled at their sources (Fuggle & Rabie, 1994:483).

5.3.2.3 RESOURCE DIRECTED MEASURES

In terms of s27 (RSA, 1998:44), the authorisation of a water use must take certain aspects of the resource into account, such as the class and resource quality objectives of the water resource to be used. A national resource protection **classification** system must be established according to **s12** of the NWA. The policy is that the level of protection for a component of the resource should be determined in accordance with a set of **objectives** for a particular catchment, that are to be the basis for water environmental quality management, and that these objectives should include all factors needed for a water resource to function, such as quality, quantity, etc. (DWAF, 1997a:19). The objectives for each element of the resource must indicate the level of use that is deemed **acceptable**, and unlikely to damage a water resource beyond repair. The approach emphasises the involvement of water users and other stakeholders in the establishment of these objectives. The term "resource quality" is introduced to describe the health of all the components of a water resource, including vegetation and animal communities and their habitats (see Figure 6, page 29). On the basis of the resource protection objectives, resources will be grouped into a number of protection classes, each requiring a different level of protection depending on the existing status of the resource and the future management or development potential of the resource. Where a high level of protection is required, for example where the main use of the resource is recreation or tourism, or where the resource has already been degraded to a state where it is no longer able to function properly, the objectives will be strict, demanding a low risk of damage and the use of great caution (DWAF, 1997a:19).

5.3.2.4 *STEPS IN THE ASSESSMENT*

On the basis of the above discussion and the theory of risk harmonisation introduced in Chapter 3, the assessment approach itself should include the following steps:

1. A **Hazard Identification** phase, during which a potential or actual waste stream or existing environmental situation is identified, on the basis of regulatory criteria and levels of exposure.
2. A **Hazard Assessment** (Exposure (Dose) – Response Assessment) phase. A mechanism for determining the potential or actual hazards posed by the waste (waste hazard factor), on the basis of the nature of the waste itself, should be developed for implementation as part of the procedure for this phase.
3. An **Exposure Assessment** phase. A mechanism for determining the **probable** or **actual** action-related or site-specific exposure levels (estimated environmental exposure or protection factors) should be established.
4. A **Risk Estimation** phase. A mechanism for **estimating the risk** (actual level of exposure to harm) posed by the proposed or existing waste disposal or discharge should be formulated, and should consist of a comparison between the waste hazard factor and the environmental exposure or protection factor.

5.3.3 RISK CHARACTERISATION

Depending on the tier of assessment, once either the actual concentration, Estimated Risk Exposure Level (EREL) or Estimated Risk (ER) has been determined, it can be compared with the regulatory standard concentration, optimum exposure level (ROEL) or the Acceptable Risk (AR). The outcome of this comparison can be used to select the BPEO in a regulatory decision-making hierarchy. A Risk Characterisation Quotient (RCQ) (also "Margin of Exposure" (MOE) (Asante-Duah, 1993:99)) can be obtained by dividing the AR with the ER (quantitative assessments), the EREL with the ROEL (semi-quantitative assessments), or the actual concentration with the standard concentration (qualitative assessments).

An RCQ larger than unity would indicate a polluting action. For example, if the ROEL is equal to 5 for a specific action, and the EREL is 10, the RCQ will be 2. This RCQ can furthermore give an indication of the level of regulatory involvement required, as well as of the priority of concern that should be given to the disposal or discharge activity. Priority attention can be given to those actions with very high RCQs. For example, when a different action in the above scenario has an RCQ of 100, it therefore needs more urgent attention than the action with the RCQ of 2. This can be taken further when limited human resources have to be assigned to manage a plethora of discharging actions.

Conversely, if the EREL is equal to 2 for the action discussed above, the RCQ will be 0.4, which would indicate a situation that can probably be sustained. Therefore, if the EREL or ER is less than the ROEL or AR, the RCQ is small, and the discharge action can be regarded as a sustainable use. The BPEO can be selected by finding the most cost-effective risk-reduction option that will result in an RCQ of < 1.

A further application of the RCQ could be the setting of waste discharge charges for actions where the RCQ exceeds unity, since the polluter pays principle is incorporated in the NWA through s56(5), which provides that the Minister may from time to time, after public consultation, set a pricing strategy that may provide for a differential rate for waste discharges, taking into account (RSA, 1998a:72):

- the characteristics of the waste discharged;
- the amount and quality of the waste discharged;
- the nature and extent of the impact on the water resource caused by the discharge;
- the extent of deviation from prescribed standards and management practices; and
- the extent and nature of monitoring of the effect of the discharge on the resource.

Each unit of increase in the RCQ could result in a higher waste discharge charge on a sliding scale based on corrective action costs.

5.3.3.1 REMEDIATION AND TREATMENT

Depending on the outcome of the assessment, remediation or treatment could be required as risk-reduction measures. Such measures have been discussed in sections 2.4.2, 3.2.4, 3.3.3, and 3.3.4. Once an option for a risk-reduction measure has been identified, the effects of its implementation must be re-assessed in order to determine whether the RCQ will reflect a BPEO situation. It is a requirement of the NWA that clean-up and rehabilitation of water resources that have already been polluted must be specifically addressed. Different options can then be compared to determine the cheapest option that will result in an RCQ < 1.

5.3.4 TYPES OF AUTHORISATIONS

The circumstances that will determine which type of authorisation will be issued for a specific water use and the different legal options for regulating particular water uses are discussed below.

5.3.4.1 GENERAL AUTHORISATIONS (SECTION 39)

The aim of General Authorisations is to set a cut-off point below which strict regulatory control is not necessary, or in areas where water stress is not eminent (Stein, 1999:10). Water uses below levels specified in the General Authorisations should constitute use at or below the *de minimis* or threshold action level. The use of water under a general authorisation as published in the *Government Gazette* (according to a procedure established after public consultation in terms of s39 of the NWA) does not require a licence unless the general authorisation is revoked, in which case licensing will be necessary (RSA, 1998a:54).

5.3.4.2 EXISTING LAWFUL WATER USES (SECTIONS 32 TO 35)

S32 identifies water uses which were authorised under governance of an Act that has been repealed by the NWA (such as the 1956 Water Act), as **existing lawful water uses**, subject to the requirement that such water use has taken place at any time during a period of two years prior to the date of commencement of the NWA. A person may apply to have a water use that is considered lawful declared as such by a responsible authority in terms of s33 of the Act. The information required for licence applications in terms of s41 is also necessary for an application made in terms of s33 (RSA, 1998a:50).

5.3.4.3 LICENCES (SECTIONS 40 TO 52)

A person who uses water in a manner that is not covered under a general authorisation, or who wishes to use water in a manner that has not been declared as an existing lawful use, may only use that water under the authority of a licence (s4,RSA, 1998a:20), which must be applied for according to ss41 and 43 of the NWA. Licences will only be issued if the use is an "optimum beneficial use", i.e. at or below the Acceptable Risk, ROEL or standard. In terms of ss43 to 48 (RSA, 1998a:58-64), **compulsory applications** for licences will be required, under certain circumstances (e.g. in areas which are under water stress), from **all** water users using a particular water resource or in a specific geographical area, irrespective of whether or not their water use has been authorised by a general authorisation or declaration of an existing lawful use.

5.3.4.4 DISPENSING WITH LICENCE REQUIREMENTS

In the event that the licensing authority is satisfied that the purpose of the NWA will be met by the granting of a licence, permit or other authorisation under any other law, this authority may either dispense with the requirement for a licence in terms of s22(3), or may combine the various licence requirements of other organs of state into a single licence (s22(4)). These provisions are of particular importance with regard to the disposal of certain types of waste on land, since the provisions for permitting a waste disposal facility in terms of s20 of the ECA are still in force. However, since the definition of waste in the NWA is more extensive than the definition of waste in the ECA, the ECA will not be valid in all instances or circumstances where waste is or was disposed of on land. Such circumstances could include, *inter alia* the following:

- If a waste disposal site was closed prior to 1990, but is causing deterioration of the resource quality, a licence may be issued to control the effects of such a site on the environment.
- A waste disposal site may be constructed, which cannot be regulated in terms of s20 of the ECA, but which can be regulated under the NWA (for example a site for the disposal of builders' rubble contaminated with mercury (e.g. Thor Chemicals), for the disposal of sediment resulting from the purification of water (e.g. Vaalkop Dam) or the cleaning of a dam which has silted up (e.g, Centurion Town Council), for the irrigation of water containing waste (a controlled activity in terms of section 21(e)), for the disposal of sewerage sludge, or for contaminated areas, evaporation ponds, slimes dams, etc.);

- In some instances, where water stress is experienced or where the resource quality must be protected, holders of permits under the ECA could be compelled to apply also for licences under the NWA when a Notice to this effect is published in the Government Gazette (compulsory application).

5.4 PROPOSED SEMI-QUANTITATIVE ASSESSMENT PROCEDURE

For a semi-quantitative assessment, the responsible authority should set out the rules for the determination of the actual intrinsic hazard posed by the waste, the actual protection offered by the facility or the capacity of the resource to assimilate the waste disposal action, as well as the actual exposure of the environment to the effects of the action. Second tier assessments can be useful when the generator of the waste does not want to incur additional expenses on determining estimated risk quantitatively, and are considered sufficient when the parties involved are satisfied with the outcome of the assessment. The assessment phase that is incorporated into the decision-making hierarchy, as discussed in section 5.3.2, is illustrated in Figure 22 below (adapted from Asante-Duah, 1993:60; and DWAF 1995:30).

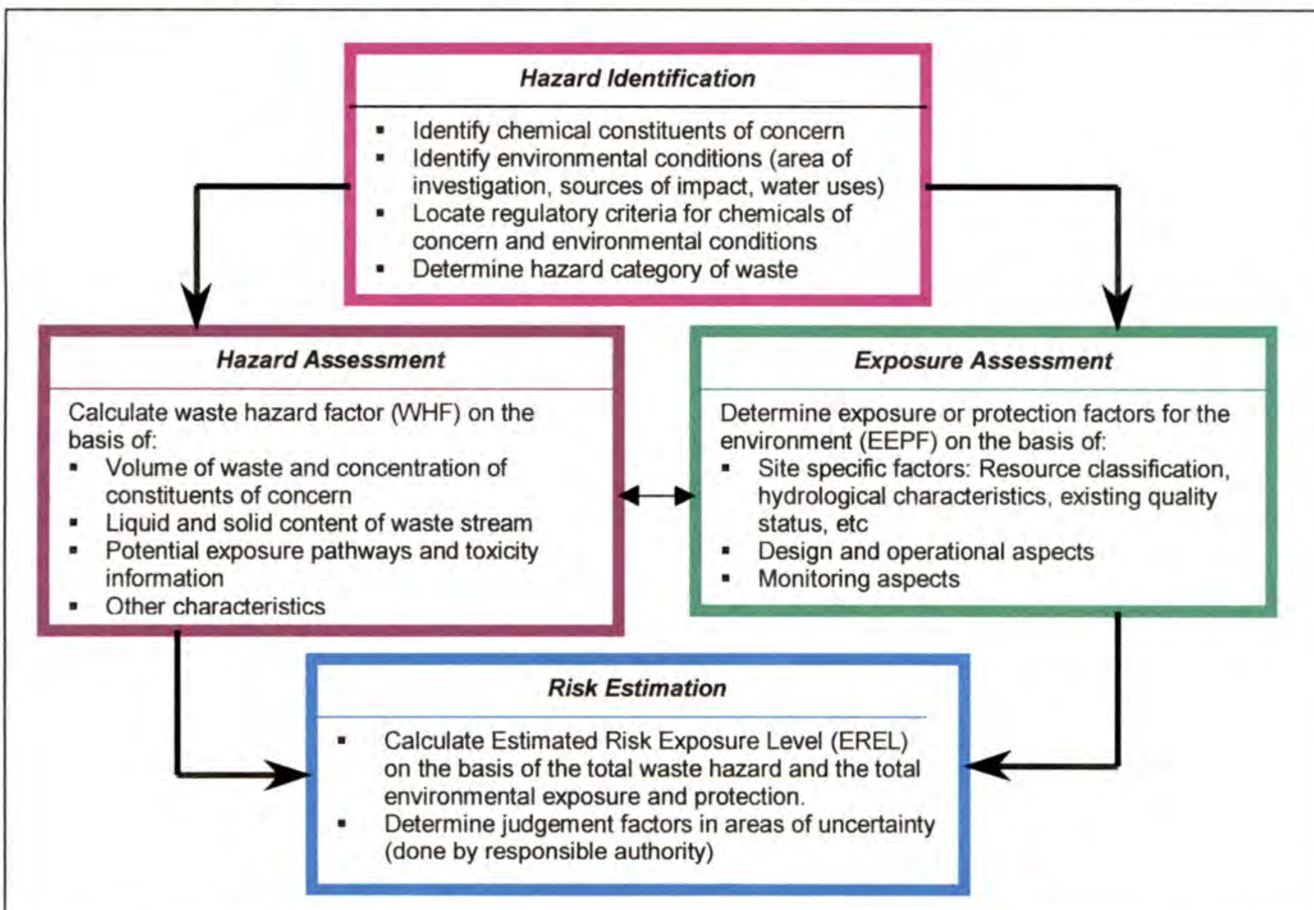

Figure 22: Proposed semi-quantitative assessment of intended or actual/historic disposal or discharge actions

It is not within the ambit of this study to indicate the details of a prescribed semi-quantitative assessment procedure, but sections 5.4.1 to 5.4.4 below suggest some factors that should be taken into consideration in the establishment of such a procedure.

5.4.1 HAZARD IDENTIFICATION

When the disposal of waste on land or into a resource is being evaluated from a risk perspective, the risk assessment process requires a detailed identification of the proposed releases as well as of the characteristics of the receiving environment (Farmer, 1997:7). On the basis of the political determination of acceptable risk, a regulatory categorisation of waste according to its actual or potential aggregate risk, in terms of both non-value-based and value-based criteria, has been suggested (see Figure 8, page 31, Table 12, page 89, & **Annexure A**). In the assessment of a potential or existing waste stream, these criteria can be used in the hazard identification phase to determine the category of the waste under investigation. This could assist in identifying the hazard category of the waste. Both non-value-based and value-based criteria may also be used to identify hazards associated with existing environmental conditions or disposal and discharge scenarios. For example, the disposal of a waste with high moisture content on land, in an unprotected site situated in the 1 in 50 year floodline of a river, constitutes a potential high-risk situation. Once the potential or existing hazard has been identified, the next step in the risk assessment can be followed according to the relevant regulatory criteria, e.g. for some of the non-value-based criteria listed in Table 12, a more detailed risk assessment is required when high uncertainty could exist regarding the manner or conditions under which the waste will be disposed of into the environment.

5.4.2 HAZARD ASSESSMENT

It is evident that effective waste management relies heavily on the effective assessment of waste, and that such assessment must determine whether a waste has the potential for re-use, could be potentially harmful and holds the risk of pollution, or can be regarded as being present at an acceptable level. Once this determination has been conducted, the BPEO for managing the waste can be determined. According to Blowers (1994:72), environmental planning should highlight the occurrence of potentially hazardous materials and indicate options for dealing with them. To determine what the BPEO should entail for such *activities and interventions*, it is evident that information must be obtained with regard to the waste that is to be managed, especially information regarding its components and their potentially hazardous nature. Furthermore, waste may also contain certain components which may be unwanted for one type of activity, but which are regarded as a resource for another activity or by another sector of society. In the calculation of the actual intrinsic hazard posed by the waste, i.e. the "Waste Hazard Factor" (WHF), the following should be taken into consideration:

- The volume of waste to be disposed of. The greater the volume the higher the risk of pollution.
- The concentration of the most hazardous components in the waste stream. A high concentration will obviously indicate a high level of risk. When the intention is to dispose of the waste on land, and the actual concentration indicates a high level of risk, the mobile or leachable concentration may be used to determine the risk to the environment.

- The percentage of liquid content in the waste stream when the intention is to dispose of the waste on land. The higher this percentage, the higher the risk of leachate generation.
- The total suspended and dissolved solid content of the waste stream if the intention is to dispose of the waste in the water resource. One of the most worrying unassessed risks of this type of disposal is sedimentation of our dams and rivers, which should be addressed.
- The most prominent exposure pathway through which the hazard will manifest in the applicable disposal scenario, and the extent of the possibility that this pathway could be involved in realising the hazard (pathway factor, PF).
- Any other physical or chemical characteristic of the substance which could result in an elevation or reduction in the intrinsic hazard posed by the waste, such as cancer slope factors (characteristics factor, CF).

The Waste Hazard Factor for disposal on land could therefore be determined as follows:

$$\boxed{\textit{WHF (land disposal)} = f(\textit{Volume x Concentration x \% liquid content x PF x CF})}$$

The WHF for disposal into a resource can be calculated according to the following equation:

$$\boxed{\textit{WHF (resource disposal)} = f(\textit{Volume x Concentration x \% solids content x PF x CF})}$$

The WHF should be indicated on the product during manufacturing so that the correct disposal option can be selected when the product becomes waste, in order to ensure cradle to grave management of materials that could end up as waste in the environment. This is particularly important with regard to everyday consumables, especially "solid" types of materials, such as fluorescent tubes, printer cartridges, cosmetics, batteries, paints and other domestic products which may pose a long-term risk to the environment once disposed of. This will make the correct choice of disposal option easier for the person or company dealing with the material when it is time to dispose of it.

It must also be noted that once the Waste Hazard Factor has been determined for the specific disposal or discharge action, it does not change due to the implementation of risk-reduction measures aimed at the protection of the specific medium of disposal. The WHF will only be affected by risk-reduction measures aimed at the source, e.g. treatment. If the waste is untreated, the WHF indicating the intrinsic **hazard** remains the same, although the **risk** can be decreased by the implementation of risk-reduction measures aimed at the protection of the environment.

5.4.3 EXPOSURE ASSESSMENT

The protection offered by the environment, or the exposure (vulnerability) of the environment, when waste is disposed of in the resource, or in a manner that may affect the resource, will depend on site-specific factors pertaining to the specific component of the resource.

5.4.3.1 EEPF FOR WASTE DISPOSAL ON LAND

Waste disposed of on land, be it in a landfill site or in another manner, creates potential risks to the environment. The decomposition of waste disposed of on land holds the potential for additional impacts on specifically the ground water component of the water resource. Site-specific environmental and engineering factors pertaining to the landfill site or disposal area will determine the protection offered by the site or the vulnerability of the environment when the waste is disposed of on land. Some of these factors should always be used to determine the Environmental Exposure or Protection Factor (EEPF), while the presence of others can be used to improve the EEPF when they are implemented. When determining the category of a land-based disposal facility or activity, the following should be taken into consideration for the calculation of the EEPF:

- **Site selection factors:** aquifer classification, geological and climatic conditions, presence and adequacy of buffer zone, etc.;
- **Engineering and design factors:** presence or absence of protective layers, type of protective layers, integrity of protective layers, design of leachate and storm water management systems, size of the exposed area (the larger the site the higher the risk of exposure);
- **Operational factors:** factors that could give an indication of the actual impact of the site on the environment, and therefore the sustainability of the management of the site, could include: compaction and cover, presence and management of reclaimers, amount of leachate produced, leachate treatment mechanisms, storm water management mechanisms, co-disposal ratios, biogas management mechanisms, implementation of internationally recognised environmental management systems (i.e. ISO14001), adequacy of monitoring systems, etc.;
- **Monitoring factors:** For example, when a landfill site has taken the total load of a specific contaminant, this will be indicated by an increasing trend in the concentration of this contaminant in the leachate.

The EEPF for **waste disposal on land** could therefore be represented as follows:

$$EEPF\ (land) = f\frac{\text{Protection offered by}}{\text{Exposure due to lack of}}\left(\text{Site selection factors} \times \text{Design factors} \times \text{Operational factors} \times \text{Monitoring factors}\right)$$

It should be evident that the EEPF of a specific site will not be the same at all times. It will depend on a number of site-specific aspects and the permit holder or operator should calculate the EEPF of his landfill site on an annual basis and submit this proposed EEPF to the relevant responsible authority, who will review the submission before the value is confirmed. Therefore, as part of the ongoing determination of the EEPF, regular analyses of the leachate must be conducted to determine increasing trends for specific contaminants, or the presence or absence of potential pollutants in the leachate, which may indicate the reduced ability of the waste disposal site to contain particular contaminants. Once such a contaminant has shown an increasing trend in the leachate, disposal of wastes containing this contaminant must be terminated. The same applies in the monitoring of the level of constituents in monitoring boreholes. Should it be considered necessary, DWAF can review the EEPF of a specific site more regularly. The EEPF for a specific landfill site should be displayed at the entrance of the site to indicate the types of waste that can be accepted at the site. The higher the EEPF, the more effective is the protection offered by the landfill site and the less the exposure of the environment. Sites with a lower EEPF offer less protection to the environment. The allocation of such a factor, will improve standards of site-selection and -design, as well as of operation and management, since the permit holder or landfill operator will be able to accept waste types for which a higher disposal rate can be charged. Some suggestions for the calculation of an EEPF for land-based disposal are contained in **Annexure C**.

5.4.3.2 EEPF FOR WASTE DISCHARGE INTO A RESOURCE

The determination of an EEPF for discharge into the water resource relates closely to the determination of assimilative capacity. In this regard, the following should be taken into consideration:

- **Hydrological characteristics:** DWAF (1995:107) states that hydrological considerations, such as stream-flow characteristics (i.e. ephemeral, intermittent, perennial) and mean annual runoff, should be taken into consideration when determining assimilative capacity. Other characteristics such as topography, geology, climatic conditions, soil and vegetation should also be considered.
- **Baseline quality of the resource:** The existing quality of the resource indicates its capacity to offer protection when additional contaminants are introduced, or the exposure it already suffers as the result of an ongoing action. This can be used to estimate the assimilative capacity.
- **Operational factors:** If waste from a treatment facility is discharged into the resource, the same applies as for the determination of the EEPF for land disposal, since a high standard of operation will reduce the risk of operational failure. Furthermore, the successful implementation of internationally recognised environmental management standards such as ISO14001 at a company will result in an increased level of responsibility for co-regulation.
- **Monitoring factors:** When monitoring of the resource downstream of the discharge indicates no adverse effects, and monitoring of the discharge itself indicates that the discharge action is conducted responsibly, within the specified standard and over time, the protection of the environment is assured.

The EEPF for **discharge into a resource** can therefore be determined as follows:

$$EEPF\ (resource) = f\,\frac{Protection\ offered\ by}{Exposure\ \ due\ to\ lack\ of}\,(Hydrological\ factors \times Baseline\ quality \times Operational\ factors \times Monitoring\ \ factors)$$

When determining the EEPF for disposal into a resource, the importance of the resource classification and Reserve determination as specified in the NWA is evident.

- **Requirements of the users** of the resource: Although an acceptable risk level should be determined politically, the users of a specific resource may decide on a catchment management basis that this risk level is not acceptable to them, since they require a higher level of protection for specific resource use reasons, e.g. tourism, aquaculture, mariculture, irrigation, etc. It must, however, be noted that it is important to refrain from using chemical concentrations as quality objectives, since this leads to conflicts of interest, and merely represents a tier 1 assessment. When a decision is made by the users of a catchment to increase or decrease the acceptable risk level determined nationally, such a decision must be properly justified, and an alternative risk value (i.e. 1 in 10^{-5}) may be set, which could lead to **the recalculation** of quality requirements specified as concentrations.

➤ **Characteristics of the resource**: The risk posed by the action to those components of the resource that must be "reserved" for specific purposes, according to the NWA, must be eliminated, and only the assimilative capacity available after subtraction of the reserve can be used in this calculation. It may also be necessary to set the level of protection more strictly for a certain period of time, as a management measure to improve the quality of a badly contaminated river that requires more protection until such time that it recovers.

This mechanism can also be used for the classification of resources on the basis of their existing characteristics and baseline qualities. Resources that are already polluted will offer low protection (due to lack of assimilative capacity), and will therefore have a low EEPF.

Depending on the EEPF, disposal facilities or discharge activities could then be categorised as, for example:

☞ Activities or facilities which pose an increased risk of harm to the environment, since they offer no protection and high exposure (low EEPF); or

☞ Activities which pose a low risk that is within the limits of the carrying capacity of the environment and that can be regarded as a beneficial use of the environment, owing to protection factors present at the point of disposal (high EEPF).

Annexure B expands on these categorisations. Such categorisations should, *inter alia,* also have the aim of minimising the negative perceptions of lay terms such as "toxic waste dumps", since a newly-constructed and well-operated facility used for the management of intermediate or low-risk waste can hardly be seen as posing a risk to the environment or being termed "hazardous".

5.4.4 RISK ESTIMATION

The actual level of exposure to harm posed by the proposed or existing waste disposal or discharge action can thus be characterised by comparing the WHF and the EEPF. As discussed in Chapter 2, risk is a function of hazard, exposure and protective factors. The aggregate Waste Hazard can thus be calculated from the hazard factors of all contaminating substances present in the waste. This can then be compared with the total or aggregate values for the Environmental Exposure or Protection Factor. Uncertainties can be addressed by introducing judgement factors. The estimated level of exposure to risk (or Estimated Risk Exposure Level, EREL) can then be determined according to the following calculation:

$$\text{Estimated Risk Exposure Level (EREL)} = \frac{\sum WHF}{\sum EEPF} \quad x \quad WJF \quad x \quad EJF$$

Any uncertainties associated with the potential hazard of the waste, for example when its characterisation has not yet been optimised by detailed analysis, can be incorporated into a Waste Hazard Judgement Factor (WJF). Also, if there are any uncertainties associated with the potential exposure of the environment (e.g. uncertainties with regard to the presence of sensitive species), this can be incorporated into an Environmental Judgement Factor (EJF). The responsible authority determines these factors, and the applicant must therefore calculate the EREL using 1 as the default value for these factors, but indicate uncertainties in the assessment in order to guide the judgement by the authority.

Calculating the aggregate EEPF on a site-specific basis in this way would assist in establishing the risk posed to the environment resulting from a specific action. Cases where the protection offered by the environment is low, while the exposure of the environment is high, will result in a low EEPF, and when the WHF is high, the resulting EREL will be even higher. Conversely, the EREL will be lower for the same waste type, if the protection offered is high and the exposure of the environment is low. This means that waste with a relatively high inherent hazard can be disposed of or discharged in a manner that will pose a low estimated risk, and such disposal could be considered sustainable, depending on how the EREL compares with the Acceptable Risk. For example, a contaminated site could be regarded as having a high risk of harm for the environment, and after the BPEO for remediation and pollution control measures has been implemented, the risk category of the site could change to low.

5.5 SUMMARY

The proposed framework makes provision for *proposed actions* (prospective scenarios), and *existing or historic actions* (retrospective scenarios), including the remediation of historical disposal or discharge actions that are causing pollution. It is based on the principles of sustainability, incorporates the hierarchy of options for waste management as discussed in chapter 2, and contains a central assessment phase, which guides the decision to be made regarding the management of the proposed or existing action. This framework thereby effectively addresses the implementation of the BPEO for risk-reduction and remediation. It is however, not only a technological approach, but also incorporates the objectives of users in establishing the BPEO. It gives an indication of the type of authorisation, the level of regulatory involvement required in various scenarios, as well as priorities for regulatory intervention on the basis of the seriousness of the impact of the disposal or discharge activity on the environment, including society. The framework also incorporates a justifiable scale for the establishment of waste discharge charges, thereby giving guidance in the implementation of the polluter pays principle.

An assessment approach based on the principles of sustainability will ensure that decisions regarding a proposed or actual action or activity can be guided in a scientific manner, while taking cognisance of non-scientific factors (e.g. socio-economic aspects) as stipulated in s27 of the NWA.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This study set out to investigate whether or not the existing mechanisms that are used to evaluate waste disposal or discharge activities lead to effective decision-making by distinguishing successfully between sustainable use and pollution. In this chapter, conclusions are drawn regarding the requirements for an assessment and decision-making framework that is based on the principles of sustainability and that can be used under the newly-promulgated National Water Act of 1998, and regarding the performance of the existing mechanisms in terms of these requirements. Lastly, recommendations are made for the establishment of a harmonised regulatory framework that will guide decision-making towards the implementation of the Best Practical Environmental Option.

6.2 CONCLUSIONS

The internationally accepted Principles of Sustainability, the concept of pollution and the hierarchy of options for Waste Management were investigated in chapter 2. The practical implications of these principles and concepts when disposing of waste or discharging water containing waste, as well as the new legal tools aimed at regulating these actions were examined in chapter 3, along with some theoretical aspects relating to risk analysis. On the basis of the study of these concepts, certain conclusions were reached, which lead to the establishment of criteria used in chapter 4 for the evaluation of the current mechanisms. Conclusions drawn from this evaluation lead to the suggestions contained in chapter 5 for the implementation of a harmonised regulatory framework for assessment and decision-making regarding waste disposal and discharge actions.

6.2.1 CONCLUSIONS FROM THE STUDY OF THEORETICAL CONCEPTS AND LEGAL REQUIREMENTS

An integrated framework aimed at distinguishing between sustainable use and pollution should be based on the following internationally-accepted Principles of Sustainability:

1. The Precautionary Principle
2. The Polluter Pays Principle
3. The "Cradle to Grave" Principle
4. The Principle of an Integrated and Holistic approach to the environment
5. The "Carrying Capacity" Principle
6. The Principle of the Consideration of Alternatives
7. The Principle of Continuous Improvement
8. The Principle of Accountability and Liability
9. The Principle of Transparency and Democracy

The **requirements for a decision-making framework** that is based on these Principles, and that incorporates the concept of pollution, the hierarchy of options for Waste Management, the new legal requirements and the theory of risk analysis, are as follows:

1. The decision-making framework should be based on the hierarchy of options for decision-making for sustainable waste management, addressing **waste minimisation** initiatives as a first priority before determining **disposal or discharge management** options.
2. The decision-making framework should contain a **strong procedural** approach that is based on the **assessment of risks** to determine **disposal or discharge management** options, so that disposal and discharge actions that are sustainable can be distinguished from those that are polluting (NEMA requirement & Brundtland Report 1987, in Farmer, 1997:6).
   2.1. It should be aimed at **preventing pollution**, and should contain **strict prescriptions** regarding how to deal with extremely hazardous sources as a minimum requirement (e.g. waste streams of concern that **cannot be disposed** of on or discharged into the environment without pre-treatment) in order to protect **public safety.**
3. The **same principles** should apply for the assessment of impacts, irrespective of where in the hydrological cycle it occurs, and decision-making should be based on **one set of rules** or criteria (Fuggle & Rabie, 1994:665), where the water resource is regarded as **indivisible**, and impacts on its different components are assessed in an integrated manner.
4. The decision-making framework must make provision for the integrated assessment of **all potential hazards** posed by **proposed, existing and historical** actions.
5. Decisions should be based on a political determination of **acceptable risk to the human population,** which can be related to a prudent national policy that is in accordance with a political determination of optimum use (Fuggle & Rabie, 1994:617).
   5.1. The **acceptable risk** determined should prevent harm to humans and place **people and their needs** at the forefront of the decision-making process (NEMA requirement).
   5.2. It is important that a **clear cut-off point** is established to distinguish between a **risk that is acceptable**, below which the introduction of a substance into the environment does not constitute pollution, but can be regarded as a sustainable use, and a pollution risk level.
   5.3. The acceptable risk should be translated into **optimum use levels** in order to protect the right to sufficient water of acceptable quality for every citizen (Constitutional requirement). These **optimum use levels** should be expressed in value- and non-value-based criteria such as **environmental protection criteria** (e.g. fatal flaws) and **optimum levels of exposure,** which should be converted to discharge concentration **standards.**
   5.4. A mechanism for establishing **clean-up** levels for contaminated site problems must be determined on the basis of the acceptable risk, and priorities must be set for the acceptable remediation of existing or historical polluting discharges or historical disposal actions (e.g. contaminated areas).

6. The decision-making framework should also contain a ***de minimis*** risk, determined according to scientific principles, and used for **hazard identification** and **first tier** assessments.
   6.1. The *de minimis* risk should be used to deduce **conservative threshold exposure levels,** (expressed, for example, in discharge concentration **standards** or environmental concern **criteria**), which could be used to activate regulatory involvement, and below which the introduction of a substance into the environment does not require regulatory involvement.

The following conclusions can be drawn regarding the approach and procedures to be followed for the **assessment** of activities, in terms of a harmonised decision-making framework:

7. **All potential hazards and exposure scenarios** should be **identified** on the basis of the conservative exposure levels and criteria set as thresholds.
   7.1. Hazards posed by **all potentially hazardous materials and waste sources** should be addressed during the **identification**, so that planning may be directed at options for dealing with them and the risk of harm can be reduced (Blowers 1994:72).
   7.2. The **identification** should highlight **the characteristics of the receiving environment** that could be particularly vulnerable to exposure and that **cannot be used for the disposal** or discharge of waste, since the main aim should be to **protect** the environment (Principle 15, UNCED: 1992).
8. The assessment itself should follow a multi-media and multi-disciplinary approach (Fuggle & Rabie, 1994:618), integrating input from across scientific boundaries to evaluate the different components of the potential risk, namely the **source**, **pathway** and **receptor,** in a **harmonised** manner.
9. The integrated assessment must take cognisance of the characteristics of the **source** posing the **hazard** (including cumulative impacts), and the **exposure** of the resource as receiving environment **(pathways** and **receptors)**, taking into account the risk-reduction measures implemented by the user to protect the resource (NWA requirement).
10. The **hazard assessment** of the source should contain an evaluation of the **intrinsic hazard posed by the waste** on the basis of characteristics such as volume, concentration, toxicological properties and additional factors (e.g. liquid or solid content) that will influence the risk.
    10.1. The hazard assessment must make provision for a **categorisation** of waste streams (based on the level of hazards they present) in order to facilitate **prioritisation** of regulatory intervention.
    10.2. Both the **individual hazards** of individual constituents in separate waste streams, and the **cumulative impacts** of all constituents in a waste stream/substance or combination of waste streams/substances to be disposed of in a particular medium, or by means of a specific method, must be assessed (Asante-Duah, 1993:5).

10.3. The hazard assessment must make provision for the determination of the **potential hazard** that will be posed by a product during its use, as well as take the **long-term effects** once it becomes waste into consideration, throughout its product, project and service **life cycles**.

11. The **exposure assessment** should contain an evaluation of all the **site-specific characteristics of the resource** as receiving environment, and the different environmental conditions that could increase or decrease the risk of exposure (pathways and receptors).

11.1. The **exposure** assessment must make provision for a **categorisation** of exposure scenarios (based on the vulnerability or assimilative capacity of the receiving environment), and must highlight scenarios of concern in order to facilitate **prioritisation** of regulatory intervention.

12. The assessment should take cognisance of the mitigatory effects of the implementation of **risk-reduction and environmental protection measures** (safeguards or **preventative measures** implemented at the cost of the generator of the waste) in the determination of the exposure.

12.1. The standard of **design, operation and maintenance** (duty of care) of the treatment or disposal facility must be taken into consideration in the assessment of actual exposure.

13. The procedure should **estimate the actual risk** of the disposal or discharge of waste in a particular receiving environment, by comparing the results of the hazard assessment with the results of the exposure assessment.

14. Provision should be made for different **levels of assessments**, namely qualitative, semi-quantitative or quantitative, depending on the urgency of the decision, the severity of the impact, and the amount and quality of information provided. When a threat to the environment is suspected, the lack of scientific evidence should not be used as a reason to postpone cost-effective measures to prevent the potential damage (Lemons, 1996:84), but risks must be **ranked** according to their potential for realisation.

14.1. Each progressive tier of assessment should require a more detailed investigation aimed at the gathering of **information,** in order to prove that the nature of the risk is of a lesser extent than that presumed by the conservative assumption, and on which decisions can be based.

14.2. The first tier of assessment should make provision for the **quick qualitative determination** of actual or potential risks under **emergency conditions** (NWA requirement), i.e. when there is not enough time to collect more information regarding the potential impacts or where priorities for intervention management must be established. The first tier of assessment therefore entails a face-value comparison of the optimum exposure criteria set of standards with the actual hazard posed by the source, as determined by a superficial analysis of its physical and chemical properties.

14.3. The second tier of assessment should make provision for the **semi-quantitative determination** of actual or potential risks, according to a prescribed procedure that is based on accurate assumptions and models.

14.4. The third tier of assessment should entail the **quantitative determination** of actual or potential risks, for which the applicant can make use of additional models, simulations, fault trees etc, to provide an accurate estimation of the actual or potential estimated risk.

The following conclusions can be made regarding considerations that must be taken into account when **making decisions** in a harmonised framework:

15. The decision-making phase should make provision for **risk characterisation**, where the estimated risk of a specific disposal or discharge action is **compared** with the acceptable risk in order to determine the BPEO for optimum use.
    15.1. The BPEO regarding the correct **environmental medium** for the disposal or discharge should be identified by estimating potential or actual risks associated with the disposal or discharge of specific waste in different environmental media (i.e. air, land, surface water, marine environment).
    15.2. The assessment procedure should indicate what the BPEO for the **method of treatment** (e.g. desalination, ash-blending etc) of the waste stream prior to disposal or discharge is, and that this could be, in most instances, the implementation of waste minimisation measures.
    15.3. The assessment procedure should indicate the **BPEO** for the method of **disposal** (e.g. mono-disposal, co-disposal, surface impoundment etc.) **or discharge** (e.g. continuous flow, controlled release, etc) of the waste stream.
    15.4. Impacts from existing discharge actions and historical disposal, such as **contaminated areas** that are causing pollution, must be assessed according to the risk they pose to the receiving environment (including the residual risk after closure) so that the BPEO for their **remediation** and rehabilitation can be implemented.
16. It should be the responsibility of the person who is, or will be, undertaking activities that might affect human health or the environment, to implement effective safeguards against harm before the action is undertaken, or mitigatory measures to prevent the risk from being realised. The framework must therefore make provision for the implementation of **risk-reduction measures**, and the measure that provides the **most favourable comparison** between estimated risk and acceptable risk should be regarded as the most **sustainable BPEO** for that particular action, provided that the estimated risk is less than the actual risk.
17. During this assessment it should be the responsibility of the person who is, or will be, undertaking activities that might pose a risk, to demonstrate scientifically (and at the appropriate level of detail) that such activities will result in insignificant or negligible harm ("**burden of proof**" (Lemons, 1996:84)).

18. The framework must make provision for decisions that must be made in the face of uncertainty, such as when doubt exists regarding the accuracy of information, or when there is any other source of **uncertainty**. It must therefore provide for the regulatory authority to form a **judgement** regarding the management of risks (DoE, 1998:3).
    18.1. The framework must be **reasonable and realistic**, and based on the **best available information** at the level that is necessary (depending on the severity of the estimated risk) to facilitate informed decision-making by a responsible authority that is accountable to the broader society.
    18.2. Each progressive tier of assessment should **reduce the level of judgement** required in the decision to ensure an administratively fair and just procedure (Constitutional requirement).
19. The framework must also contain a mechanism for the **verification** of information provided by the applicant, since the applicant should be accountable for the information provided. Such verification could entail peer review.
20. The framework must contain a mechanism for determining **priorities** for regulatory involvement in disposal or discharge actions that cause pollution, so that limited resources can be allocated in a focussed manner. The polluting activities must be prioritised according to the seriousness of their effects, and so that it can serve as a management tool for deciding where to focus within the budgetary and human resource constraints of the responsible authority, the framework must distinguish between categories of risk.
21. The outcome of the assessment and decision-making procedure must also give an indication of the scale, and level of application, of the appropriate resource economics **(waste discharge charge)** that must be employed to prevent the continuation of polluting actions.
22. The **scientific evaluation** of the potential risk must be integrated with **socio-economic** and **political** considerations when the decision is taken.
23. Provision must be made for **public involvement** in the procedure of assessment, by giving the affected members of the public the opportunity to participate in the decision. Where appropriate, these members of the public must be able to request that the optimum exposure levels for a specific area or action are made less or more strict than the politically-acceptable risk-level set nationally.
    23.1. The framework must make provision for factors influencing **perceptions** regarding risk and environmental impacts, and must effectively communicate these to the relevant interested or affected sectors of the public.
    23.2. Information obtained during the assessment must be made available to the public (Constitutional requirement) in a manner that is **understandable** to the layperson, although the intricacies of the processes contained in such an evaluation mechanism may be of a highly evolved scientific nature, involving many complex sciences and models.

23.3. The framework must make use of **terminology** that does not create confusion due to its common usage (e.g. "contamination") or emotional connotations (e.g. "hazardous/toxic"). This implies that it must make use of language that accurately describes the real hazards posed, the protection offered by safeguards or environmental factors and, in terms of their acceptability the different resultant risks.

The following conclusions can be drawn regarding some **general considerations** that must be taken into account when developing a harmonised framework:

24. The assessment and decision-making framework itself must be improved continually by comparison of the optimum exposure levels set with actual data, re-evaluated continually on the basis of this improved **scientific knowledge base**; and amended when necessary.
    24.1. **Assumptions** in the prescribed semi-quantitative hazard and exposure assessment must be continuously reassessed on the basis of improved scientific knowledge.
25. Once the decision is implemented, the information base must be supplemented with **monitoring data**, and a regular **re-assessment** of the actual impact of the action must be conducted on the basis of this data.

The manner in which these conclusions relate to the Principles of Sustainability and the newly promulgated legal requirements is indicated in Table 9.

6.2.2 CONCLUSIONS FROM THE EVALUATION OF EXISTING MECHANISMS

Criteria for the evaluation of the current regulatory mechanisms were deduced on the bsasis of the conclusions listed above. This evaluation, as contained in Table 10, gives rise to the following conclusions:

1. Both mechanisms address some of the factors that are necessary for an effective decision-making framework, the most important of which is that they require the implementation of waste minimisation initiatives as a first priority.
2. The main factors that hamper the use of these mechanisms for effective decision-making under the newly-promulgated legislation, especially the National Water Act, are:
    2.1. The fact that two separate mechanisms exist, prevents decisions regarding the implementation of the cost-effective BPEO for risk-reduction being made from a holistic perspective, with which alternatives regarding media, methods for treatment or disposal, etc would be able to be compared in an integrated manner.
    2.2. The lack of a political determination of acceptable risk, that takes cognisance of the indivisible nature of the water resource, results in different regulatory standards being specified for comparable actions. This has the effect that there is no clear cut-off point between pollution and sustainable use, which can lead to decision-making that is neither just nor reasonable.

2.3. Although both mechanisms contain some elements of risk analysis, especially risk assessment, the lack of a formalised, strong procedural approach for determining these risks, specifically in a semi-quantitative manner, results in decision-making that is not logical, rational and methodologically consistent (Asante-Duah, 1993:112).

Individual advantages of both mechanisms as outlined in Table 10, could be incorporated into an integrated and harmonised framework. Table 10 also highlights some disadvantages which should be avoided in the establishment of such a framework, provided that cognisance is taken of the provisions of the newly promulgated NWA.

6.3 RECOMMENDATIONS

In order to arrive at such a harmonised framework, it is recommended that the following actions are implemented:

1. Facilitate a political decision on **acceptable risk** to enable decision-making regarding the BPEO. In this regard a mortality rate of one in 10^{-6} for the human population is recommended. Once the acceptable risk has been determined, a *de minimis* risk should be scientifically established. On the basis of these risks, an integrated set of **regulatory criteria** for optimum and *de minimis* exposures for waste disposal or discharge should be developed for various chemical substances, environmental conditions, exposure scenarios, protection distances, water quality standards, etc. The determination of these criteria should be similar irrespective of where or how the substance will be released.
2. Develop a **harmonised hierarchy for decision-making** in terms of the NWA, that includes a risk analysis approach which is aimed at determining the BPEO according to comparison of the estimated risk with the acceptable risk during risk characterisation.
3. Develop the **risk analysis approach**, which bases hazard identification on the regulatory criteria, and which involves a **prescribed procedure for a semi-quantitative** risk assessment.

6.4 SUMMARY

As environmental resources are reduced, it becomes important to establish priorities among competing risks in different environmental media, therefore regulators will be under increased pressure to make decisions in terms of a consistent set of guidelines for both the assessment and the management of such risks (Kamrin, 1997:8). In addition, society is asking more difficult questions about the results and implications of assessment mechanisms, such as the costs and risks of decisions, and environmental justice. The integration of the current mechanisms is a necessity in terms of the requirements of the newly-promulgated National Water Act, and such integration should be consistent with the requirements of the Constitution. The implementation of a harmonised risk analysis framework in South Africa will provide a decision-making tool, the use of which can be considered a fair and just administrative action for the management of waste disposal and discharge actions in the future.

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GLOSSARY

Since there are many (sometimes conflicting) definitions of various aspects of environmental management, it is necessary to outline the following definitions and concepts in order to prevent possible uncertainties. Some of these aspects are discussed in greater detail in some of the chapters.

TERM	DEFINITION
Aquifer (NWA definition)	A geological formation which has structures or textures that hold water or permit appreciable water movement through them.
Catchment (NWA definition)	In relation to a watercourse or watercourses or part of a watercourse, means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface water flow to a common point or common points.
Co-disposal (DWAF 1998b:G-2)	The mixing of waste with high moisture content, or "liquid" waste, with dry waste. This affects the water balance and is an acceptable practice on a hazardouswWaste site, but is only acceptable on a general waste disposal site equipped with leachate management measures
Consequences (DoE; 1998:58)	The adverse effects or harm resulting from the realisation of a hazard which cause the quality of human health or the environment to be impaired in the short or longer term.
Conservation (NWA-definition)	In relation to a water resource, means the efficient use and saving of water, achieved through measures such as water-saving devices, water-efficient processes, water-demand management, and water rationing.
Domestic waste/refuse (DWAF, 1998b:G-2)	Waste produced typically in homes and offices. Although regarded as a general waste, this waste contains medical and organic components, as well as small amounts of hazardous substances.
Environment (DEAT, 1992b)	The external circumstances, conditions and objects that affect the existence and development of an individual, organism or group. These circumstances include biophysical, social, economical, historical, cultural, and political aspects.
Environmental Management	Management skills and techniques implemented to achieve the principles of sustainability at all levels, including the macro level (governments) and the micro level (private sector). (Fuggle & Rabie, 1994:2,3)
General waste (DWAF, 1998b:G-3)	Waste that does not pose an immediate threat to man or the environment (i.e. household waste, builders' rubble, garden waste, dry non-hazardous industrial waste and commercial waste), but which may with decomposition, infiltration and percolation, produce leachate with an unacceptable pollution potential.
Hazard	A property or situation that could lead to harm in particular circumstances (DoE, 1998:58).
Hazardous (Blackman, 1996:36)	A broader meaning than toxic, "Hazardous" refer all waste types that hold the risk of harm for any reason, be it toxic, explosive, flammable, reactive, etc. An effect may be intrinsically of extrinsically hazardous.
Hazardous waste (Noble, 1992: Vol. 4, 4-5)	Since the definition of hazardous waste is completely dependent on the system used for the classification of waste, it differs from country to country. For the purposes of this study, where an environmental management perspective is adopted, the following definition, adapted from the CSIR Report, will be used: **Hazardous waste** is any waste that directly or indirectly poses a risk to human safety, human health or the environment.
Intention (DoE, 1998:58)	In waste management, refers to the generation of waste and the intended action of disposing of such waste on land.
Landfill (ISWA, 1992)	The engineered deposit of waste onto and/or into land in such a way that pollution or harm to the environment is prevented, and, through restoration, land is provided which may be used for another purpose.
Leachate (DWAF, 1998b:G-5)	An aqueous solution with a high pollution potential containing final and intermediate products of decomposition, various solutes and waste residues, arising when water (e.g. from rainfall) is permitted to percolate through decomposing waste.

TERM	DEFINITION
Pollution (NWA definition)	Means the direct or indirect alteration of the physical, chemical or biological properties of a water resource as to make it – (a) less fit for any beneficial purpose for which it may reasonably be expected to be used; or (b) harmful or potentially harmful to the welfare, health or safety of human beings; any aquatic or non-aquatic organisms; the resource quality; or property.
Probability (DoE, 1998:58)	The mathematical expression of chance (e.g. 0.20 is equal to 20% or a 1 in 5 chance) wherever this can be determined, although in many cases it is no more than a prospect which can only be expressed qualitatively. The definition applies to the chance of the occurrence of a specific event, or one among a number of possible events, in a given period of time.
Protection (NWA definition)	In relation to a water resource means- (a) maintenance of the **quality** of the water resource to the extent that the water resource may be used in an ecologically sustainable way; (b) prevention of the degradation of the water resource; and (c) the rehabilitation of the water resource
Reserve (NWA definition)	The quantity and **quality** of water required – (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 108 of 1997, for people who are now or who will, in the reasonably near future, be relying upon; taking water from; or being supplied from the relevant water resource; and (b) to protect aquatic ecosystems in order to ensure ecologically sustainable development and use of the water resource
Resource quality (NWA definition)	The quality of all aspects of a water resource including – (a) the quantity, pattern, timing, water level and assurance of instream flow; (b) the water **quality**, including the physical, chemical and biological characteristics of the water; (c) the character and condition of the instream and riparian habitat; and (d) the characteristics, condition and distribution of the aquatic biota
Responsible authority (NWA definition)	In relation to a specific power or duty in respect of water uses means – (a) if that power or duty has been assigned by the Minister to a catchment management agency (CMA), that CMA; or (b) if that power or duty has not been assigned, the Minister.
Risk (DoE, 1998:58).	A combination of the probability or frequency of occurrence of a defined hazard, and the magnitude of the consequences of such occurrence.
Risk assessment (Asante, 1998:117).	A systematic process of estimating all the significant risk factors that prevail over an entire range of exposure scenario's associated with some hazard situation.
Risk estimation (DoE, 1998:58).	Is concerned with the outcome or consequences of an intention taking into account the probability of occurrence under various exposure conditions.
Risk characterisation (DoE, 1998:58).	Is concerned with determining the significance of the estimated risks for those affected, and therefore includes the element of risk perception.
Risk management	The process of implementing decisions about accepting or altering risks. (DoE, 1998:58).
Risk perception (DoE, 1998:58).	The overall view of risk held by a person or group and includes both feeling and judgement.
Sanitary Landfill (DWAF, 1998b:G-9).	A method of disposing of waste on land without causing nuisances or hazards to public health or safety. Uses the principles of engineering to confine the waste to the smallest practical area, reduce it to the smallest practical volume, and cover it with a layer of earth at the conclusion of each day's operations or at such less frequent intervals as may be acceptable.
Sustainable development (WCED, 1987:43)	"*Development managed in such a manner that the needs of the present are satisfied without jeopardising the ability of future generations to meet their own aspirations.*" (Brundtland Report)
Sustainable Landfill (Westlake, 1997:454)	A landfill designed and operated in such a way that it minimises both short-term and long-term environmental risks to an acceptable level. (This definition recognises that while environmental pollution must be prevented, the prevention of environmental contamination might not be possible, although it is not necessarily desirable.)

TERM	DEFINITION
Toxic (Blackman, 1996:36)	Commonly describes poisonous substances that cause death or serious injury to humans by interfering with normal body physiology. Properly describes pure substances, whether or not they are a waste (e.g. "toxic substance" or "toxic chemical"). A toxic effect is imposed intrinsically
Waste (DWAF, 1997a: 1-1).	The present identification of waste according to the ECA, 73 of 1989, and as it is defined in Government Gazette No 12703, August 1990, "waste" excludes industrial waste water, sewage, radioactive substances, and mining, metallurgical and power-generating waste. These types of waste are, however, not excluded from the objectives of the NWMS, which aims to include these products in the total waste management strategy. The following definition will therefore be valid for the identification of all types of waste: **Waste** is defined as an undesirable or superfluous by-product, emission or residue of any process or activity, that has been discarded, accumulated or stored for the purpose of discarding or processing.
Waste (NWA definition)	Includes any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water resource to be polluted.
Waste Management (DWAF, 1998b:1-2)	Any activity or intervention which directly or indirectly imposes on the production, handling and ultimate disposal of waste. Entails the hierarchical implementation of the following steps: 1. Prevention of waste generation; 2. Waste recycling, 3. Recovery and utilisation; 4. Waste Treatment in order to reduce risk and/or quantity; and 5. Storage and final disposal
Watercourse (NWA definition)	Means - (a) a river or spring; (b) a natural channel in which water flows regularly or intermittently; (c) a wetland, lake or dam into which, or from which, water flows; and (d) any collection of water which the Minister may, by notice in the *Government Gazette*, declare to be a watercourse
Water management institution (NWA definition)	A catchment management agency, a water user association, a body responsible for international water management or any person who fulfils the functions of a water management institution in terms of the NWA.
Water resource (NWA definition)	A watercourse, surface water, an estuary, or an aquifer.
Waterwork (NWA definition)	Any borehole, structure, earthwork or equipment installed or used for, or in connection with, water use

ABBREVIATIONS AND ACRONYMS

ALARA	As Low As Reasonably Allowable
APPA	Atmospheric Pollution Prevention Act, 45 of 1965
AR	Acceptable Risk (as defined internationally)
ARL	Acceptable Risk Level (as used in the MRHW)
BPEO	Best Practical Environmental Option
CAPCO	Chief Air Pollution Control Officer
CF	Characteristics Factor
CNS	Council for Nuclear Safety
CSIR	Council for Scientific and Industrial Research
DEAT	Department of Environmental Affairs and Tourism
DME	Department of Minerals and Energy
DoE	Department of the Environment (United Kingdom)
DWAF	Department of Water Affairs and Forestry
ECA	Environment Conservation Act, 73 of 1989
EEC	Estimated Environmental Concentration
EEPF	Estimated Exposure or Protection Factor
EJF	Environmental Judgement Factor
ER	Estimated Risk
EREL	Estimated Risk Exposure Level
ISWA	International Solid Wastes Association
IMDG	International Maritime Dangerous Goods
IWM	Institute of Waste Management (South Africa)
LOEL	Lowest Observed Effect Level
LOAEL	Lowest Observed Adverse Effect Level
MF	Modification Factor
MRHW	Minimum Requirements for the Handling, Classification & Disposal of Hazardous Waste
MRM	Minimum Requirements for Water Monitoring at Waste Management Facilities
MRWC	Minimum Requirements: Waste Classification System
MRWD	Minimum Requirements for Waste Disposal by Landfill
NEMA	National Environmental Management Act, 107 of 1998
NGO	Non-Governmental Organisation
NOEL	No Observed Effect Level
NOAEL	No Observed Adverse Effect Level
NIMBY	Not In My Backyard
NWA	National Water Act, 36 of 1998
NWMS	National Waste Management Strategy
PAEDI	Procedures to Assess Effluent Discharge Impacts
PF	Pathway Factor
RCQ	Risk Characterisation Quotient
RDMEL	Regulatory *De Minimis* Exposure Level
ROEL	Regulatory Optimum Exposure Level
RWQO	Receiving Water Quality Objective
SABS	South African Bureau of Standards
UES	Uniform Effluent Standard
UNCED	United Nations Conference on Environment and Development
TWQG	Target Water Quality Guideline
UF	Uncertainty Factor
WHF	Waste Hazard Factor
WJF	Waste Judgement Factor
WRC	Water Research Commission

ANNEXURE A: PROPOSED CATEGORISATION OF TYPES OF WASTE

PROPOSED CATEGORISATION OF WASTE TYPES

A categorisation of wastes (see Figure 8 page 31, and sections 5.2.2.1.1 page 88 and 5.4.2 page 100) should be established on the basis of the political determination of acceptable risk, according to:

⇒ potential risk to human or public safety (extremely high risk waste),
⇒ acute potential risk to human health (serious risk waste),
⇒ chronic potential risk to human health (high risk waste), and
⇒ potential risk to the integrity of the environment (intermediate risk waste).

In a semi-quantitative procedure, this constitutes the determination of the Waste Hazard Factor (WHF), on the basis of the following:

- the physical characteristics of the waste;
- the volume and concentration of the most harmful components,
- the exposure pathways by means of which hazards associated with these constituents would be realised;
- the percentages of liquid or solid content, and
- any other characteristic that may influence the hazard posed by the waste.

1. Highly Hazardous Waste

This is a non-value-based criterion that has its foundation in the precautionary principle, and should be the starting point of any regulatory system based on risk. When the nature or physical or chemical characteristics of any waste other than domestic refuse is unknown, it will be regarded as being of the highest hazard category, and must be handled accordingly until such time as its properties, and the risks associated with them, have been determined as part of a Hazard Assessment, and its WHF had been determined.

2. "Perilous" Wastes

The term "Perilous waste" refers to waste that holds a **serious** risk of harm to public safety. Owing to its physical properties, this type of waste can cause immediate death or serious injury and/or damage to body tissue upon exposure. This waste may **never** be disposed of on land or discharged in a resource, but must be **destroyed** in accordance with the appropriate applicable legislation. It is suggested that the following SABS Code 0228 Classes represent serious risk, or "Perilous" waste:

Proposed categorisation of waste: Serious risk or "Perilous" waste

Waste Class	Associated risk	Initial action
Class 1: Explosives	Death and/or serious injury	Consult Explosives Act. Pre-treat and destroy.
Class 2.1: Flammable gases	Death and/or serious injury	Thermal destruction.
Class 3: Flammable liquids	Death and/or serious injury	Determine flash point. Treat to render >61°C.
Class 4: Flammable solids	Death and/or serious injury	Determine flash point. Treat to render >61°C.
Class 5.1: Oxidising substances	Serious injury and/or death	Treatment to neutralise oxidation potential.
Class 5.2: Organic peroxides	Serious injury and/or death	Treatment to neutralise oxidation potential.
Class 8: Corrosive substances	Serious injury and/or death	Determine pH. If pH < 6 or > 12, treat to pH 6-12.

The waste in this category must be handled and transported with extreme caution. Some initial action will always be required to render the waste less harmful, before further options for discarding can be considered. Once the initial action has been implemented, the residual material should be evaluated further to determine its waste category.

3. "Dangerous" Wastes

The term "Dangerous waste" refers to those substances that, owing to both physical and chemical properties, pose an **acute** risk to human health. This **extremely high** risk may result in poisoning, infection, disease, and cancer. The waste in this category *may **never** be disposed of on land or discharged in a resource, but must be either **destroyed or isolated** in absolute containment in accordance with the appropriate applicable legislation.* Normally, it should be managed by incineration or destruction with special approved technologies, but it may, with extreme care, be stored in protective containment facilities, such as encapsulation. The destruction, incineration, or containment of this type of waste may also be regulated by additional legislation, such as the Tissues Act. It is suggested that the following waste types, which include some SABS classes, as well as some additional classes of waste, be included in this category:

Proposed categorisation of waste: Extremely high risk or "Dangerous waste"

Waste Class	Associated risk	Initial action
Residues of treated Perilous waste types with risk factor > 1 in 10^{-4}	Unknown	Assess associated risk to determine further action
SABS Class 2.3: Poisonous gases	Disease and/or death	Consult APPA. Controlled destruction. Assess residue for disposal purposes
Bio-hazardous Medical waste	Disease and/or death	Consult Tissues Act, Health Act and Department of Health. Pre-treat (destroy by incineration)
Carcinogenic substances with cancer risk > 1 in 10^{-7}	Cancer and/or death	Contain or destroy with special approved technology
SABS Class 6.1(a): Toxic substances, including pesticides, with risk factor > 1 in 10^{-4}	Disease and/or death	Contain or destroy with special approved technology
SABS Class 6.2: Infectious substances, with risk factor > 1 in 10^{-4}	Disease and/or death	If waste is infectious, regard as medical waste. Contain/destroy with special approved technology
SABS Class 7: Radioactive wastes, with health risk factor > 1 in 10^{-4}	Cancer and/or death	Determine specific and/or total activity to assess associated risk. Consult Nuclear Energy Act (Council for Nuclear Safety) and Hazardous Substances Act (Department of Health)
SABS Class 9: Miscellaneous dangerous substances, with risk factor > 1 in 10^{-4}	Cancer, disease and/or death	Assess associated risk to determine further action
Organic solvents with risk factor > 1 in 10^{-4}	Damage to human cells	Owing to health risks and damage to clay and plastic liner systems of disposal sites: Contain or destroy with special approved technology
Pharmaceutical waste: Schedule 5 and higher	Risk to health of workers on waste sites	Consult Health Act and Department of Health. Contain or destroy with special approved technology

4. "Precarious" Wastes

High Risk waste that poses a chronic risk to human health, owing to its nature or chemical characteristics, and requires a **risk assessment** to determine treatment and disposal options, may be termed **Precarious**. This type of waste may **never** be discharged into a water resource, but must be treated in whatever way represents the BPEO for risk-reduction. When the WHF is calculated, the BPEO for risk-reduction measures aimed at the source can be determined. Once the appropriate treatment has been implemented, and following a re-assessment, the treated residue may be disposed of on land (under certain circumstances and according to the applicable legislation) in **high-protection waste disposal facilities** which, due to their EEPF, will render the estimated risk to < 10^{-6}.

Proposed categorisation of waste: High Risk or "Precarious" waste

Waste Class	Associated risk	Initial action
Residues of treated Dangerous waste with risk factor < 1 in 10^{-4} but >1 in 10^{-6}	Unknown	Assess associated risk to determine further action (e.g. treatment and high protection disposal)
All other medical waste not listed previously	Disease and/or death	Consult Health Act and Department of Health. Pre-treat (destroy through incineration or alternative approved technology). Assess associated risk to determine further action (e.g. treatment and high protection disposal)
Carcinogenic substances with cancer risk < 1 in $10^{-6}$and containing less than 1% of a class AB carcinogen. Substances containing less than 1% of a class AB carcinogen, with cancer risk < 1 in 10^{-7}	Cancer and/or death	Assess associated risk to determine further action (e.g. treatment and high protection co-disposal)
Industrial waste with low moisture content and risk factor < 1 in 10^{-4} but >1 in 10^{-6}	Disease and/or death	Assess associated risk to determine further action (e.g. treatment and high protection co-disposal)
Industrial waste with high moisture content and risk factor < 1 in 10^{-4} but >1 in 10^{-6}	Disease and/or death	Assess associated risk to determine further action (e.g. treatment and discharge, with high protection mono- or co-disposal of the brine)
Schedule 3 to 5 Pharmaceutical wastes	Risk to health of workers on waste sites	Assess associated risk to determine further action (e.g. treatment and high protection disposal)

It is important to note that this type of waste must first be treated to reduce their associated hazards, and the residues must be assessed for disposal in an appropriate facility. Such treatment could, however, lower the risk posed by the waste to such an extent that it moves down to the next category. Should such treatment not be implemented, the protection factor of the disposal facility must be increased accordingly.

5. Intermediate risk or "Uncertain" Wastes

Waste posing an uncertain, unknown or suspected **chronic risk** to human health and/or environmental integrity owing to its chemical characteristics, will be considered **Intermediate risk** waste. Following a **value-based risk assessment** to determine the correct disposal option, this type of waste may be disposed of on land in **moderate-protection waste disposal facilities,** or **discharged** into a water resource, depending on the protection offered by the disposal action, and according to the applicable legislation. Waste associated with an uncertain, unknown or suspected chronic risk to human health and/or environmental integrity should never be disposed of indiscriminately, but its total Waste Hazard Factor should be assessed to determine the correct disposal option. Under certain circumstances, such waste may be discharged **in a water resource** if the risk assessment indicates that the actual risk is < 10^{-6}, or it may be disposed of in **moderate-protection waste disposal facilities** which, due to their environmental protection factor, will render the actual risk to < 10^{-6}. The correct disposal option will be indicated by the outcome of the additional assessment. Waste in this category could include:

Proposed categorisation of waste: Intermediate Risk or "Uncertain" wastes

Waste Class	Initial action
Residues of treated Precarious wastes with risk factor < 1 in 10^{-6}	Assess associated risk to determine further action (e.g. treatment and disposal in **permitted** moderate protection disposal site according to **permit** conditions)
Pharmaceutical waste lower than Schedule 3	Land disposal in **permitted** moderate protection disposal site according to **permit** conditions
Substances containing less than 1% of a class CD carcinogen, with cancer risk < 1 in 10^{-7}	Land disposal in **permitted** moderate protection disposal site, after treatment, according to **permit** conditions
Industrial waste with low moisture content and risk factor < 1 in 10^{-6}	Land disposal in **permitted** moderate protection disposal site after treatment according to **permit** conditions (co-disposal).
Industrial waste with high moisture content and risk factor < 1 in 10^{-6}	Water resource disposal after treatment to remove solids and according to **licence** conditions
SABS Class 2.2: Non-flammable & non-poisonous gases	Consult APPA. Release into atmosphere

6. Domestic Waste

The risk involved in this category of waste is difficult to determine and can vary in degree, since it depends on quantity, origin, and content. Builders' rubble and Domestic waste streams containing solid or semi-solid material originating from households may **never** be discharged into a water resource, but **must** be disposed of in, at least, any **permitted low-protection** disposal site for domestic waste, which is being operated in terms of **permit** conditions. A low-protection site for domestic waste will be a site that was designed according to the climatic water balance. Domestic waste may also be disposed in higher protection categories of waste disposal facilities, to accommodate co-disposal at such facilities.

7. Harmless Low Moisture Content Waste (Negligible risk or "*de minimis*" waste)

Industrial waste with low moisture content includes waste which requires negligible regulatory control. However, this status can only be established once a risk assessment has indicated that the estimated risk factor < de minimis level. This waste type may **never** be discharged into a water resource, but once an assessment has been conducted, the waste may be disposed of in any **permitted** low protection disposal site for industrial waste. This implies a site that was designed according to climatic calculations and that provides for the generation of leachate based on this climatic water balance, and which is being operated according to the applicable legislation. This type of waste can be regarded as "inert", and can therefore also be effectively sourced for re-use in other applications (e.g. manufacture of building material, backfilling, etc)

8. Harmless High Moisture Content Waste (Negligible risk or "*de minimis*" waste)

Industrial waste with high moisture content includes waste which requires negligible regulatory control. However, this status can also only be established once a risk assessment has been conducted to indicate that the estimated risk factor < de minimis level. This type of waste may **never** be disposed of on land in any disposal site, but **must either be re-used within the factory premises or** be discharged in a water resource, after treatment to remove solids and in fulfilment of **general authorisation** conditions.

ANNEXURE B: PROPOSED CATEGORISATION OF DISCHARGE OR DISPOSAL ACTIONS

As discussed in sections 5.2.2 (page 89) and 5.4.3 (pages 101 to 104), disposal or discharge activities or actions can be categorised on the basis of the calculated EEPF. Such categorisation can be established as outlined below:

1. Categories of land based disposal activities

For land-based disposal facilities or activities, the EEPF is calculated as a function of site selection, design, operational and monitoring aspects, and on the basis of this determination, these facilities or activities can be categorised as follows:

EEPF	Category of site	Associated Risk	Activity
Undetermined	Contaminated areas	Unassessed, therefore serious risk of pollution.	Polluting
Extremely low	Extremely high risk polluted sites	No protection and high exposure. Extremely high risk of pollution.	
Very low	High risk polluted sites	No protection and medium exposure. High risk of pollution.	
Low	Moderate risk polluted sites	No protection and low exposure. Moderate risk of pollution.	
Acceptable, LOW range	Small disposal sites for Domestic waste	Low protection and medium exposure. Site-selection, design, operation, etc are according to relevant standards.	Sustainable use
Acceptable, HIGHER range	Large, Medium or Small Low-protection disposal sites for domestic or industrial waste		
High	Moderate protection mono- or co-disposal sites (current: H:h)	Moderate protection and medium exposure. Site-selection, design, operation, etc. are according to relevant standards, and leachate management is addressed in design.	
Very high	High protection mono-or co-disposal sites (current: H:H)	Moderate protection and low exposure. Site selection, design, operation, etc are according to highest standards.	
Extremely high	High protection encapsulation facilities	High protection and low exposure. Site selection, design, operation, etc are according to highest standards.	
Undetermined but negligible, governed by general authorisation	Communal Domestic disposal sites, used for domestic waste disposal	Negligible.	*De minimis*
	Domestic disposal site on farms used for domestic waste disposal	Negligible.	

It is suggested that the current categorisation, as adopted in the Minimum Requirements, be adopted for Low-protection domestic and industrial disposal sites, namely: Small, Medium, and Large depending on the volume of domestic waste handled at the site.

2. Categories of actions involving discharge into the Resource

Based on hydrological characteristics, baseline quality, user requirements, resource classification, , operational and monitoring aspects an Environmental Exposure or Protection factor is determined according to which discharge activities into a resource can be categorised:

EEPF	Description of Action	Associated Risk	Activity
Undetermined	Discharge of waste into a water resource	Unassessed, therefore serious risk of pollution	Polluting
Low	Discharge of waste into a water resource, with aggregate risk higher than acceptable risk level	No protection and high exposure. No assimilative capacity. Serious or high impact.	
High	Discharge of waste into a water resource, with aggregate risk between acceptable risk and *de minimis* levels	High or moderate protection and low exposure. Risk of impact is within assimilative capacity.	Sustainable use
Undetermined but negligible	Discharge of waste into a water resource with aggregate risk lower than *de minimis* risk level	High assimilative capacity available. Low impact.	*De minimis*

This categorisation can be expanded further, making allowance for the classification of the resource, etc.

ANNEXURE C: SEMI-QUANTITATIVE CALCULATION OF THE EEPF FOR LAND BASED DISPOSAL ACTIVITIES

SEMI-QUANTITATIVE CALCULATION OF THE EEPF FOR LAND BASED DISPOSAL ACTIVITIES OR FACILITIES

As discussed in section 5.4.3.1 (page 102), the EEPF for waste disposal on land could be represented as follows:

$$\textit{EEPF (land)} = f\frac{\textit{Protection offered by}}{\textit{Exposure due to lack of}}\left(\textit{Site selection fators x Design factors x Operational factors x Monitoring factors}\right)$$

The following are suggestions regarding the semi-quantitative determination of this Factor:

a) Site-Selection factors

The following aspects of a specific disposal site will always be the same, once it has been established:

- The confirmed WASP index score for the site;
- The climatic conditions at the site and its potential to generate leachate (B+ or B-);
- The classification of the aquifer under the site.

The **site-selection value** can therefore be determined as follows:

WASP Index Score	Aquifer classification	Leachate Value		Value
0 – 4	Low Yield (<1l/sec)	Sporadic leachate generation (B-)	**2**	**1**
4 – 5	Medium yield (1 – 5 l/s)	Significant leachate generation (B+)	**4**	**10**
5 – 10	High and Very High Yield (> 5l/s)			**100**

$$\textbf{Site Selection Value (SSV)} = \textbf{WASP Value} \times \textbf{Leachate Value} \times \textbf{Aquifer Value}$$

OR:

SSV = WASP Index x Aquifer yield x Leachate value

This means that, for a landfill site situated in an area with rainfall higher than evaporation (B+), and a WASP Index score of 3, situated on an aquifer yielding 0.8l/s, the SSV will be 10X100X100 = 100 000, **OR** 3 x 0.8 x 4 = 9.6.

b) Design factors

The engineering and design features of a landfill site may change over time. It may also happen that, for instance, a liner failure occurs, in which event the protection offered is eliminated. The following factors must be taken into consideration when determining this value:

- The size of the landfill site. (The larger the site, the greater the extent and significance of the environmental impact)
- The permeability of the clay layers in the lining system. Since plastic liners may tear or become damaged, the maximum outflow rate in the clay layers, measured in metres per year, as determined in the leachate collection system, will be used to determine the protection value of the lining system. The Minimum Requirements specify the following maximum outflow rates:
    - For G:B+ landfills: 0.3m/y
    - For H:h landfills: 0.1 m/y
    - For H:H landfills: 0.03m/y

OR

The value allocated to the design of the liner may be determined as follows:

Liner standard according to 1998 Minimum Requirements	Liner Value
Higher than H:H	2000
H:H	1500
H:h	1000
Hazardous Lagoon	750
G:M:B+ and G:L:B+	500
Lower than G:B+	10
No lining	1

- The integrity of the lining system. This will be indicated by the absence of leachate in the leachate detection layer. Should the liner integrity be breached, leachate will be present in this layer, and the waste site may no longer accept waste unless the problem is rectified. This means that the integrity of the liner is represented by the value 1 if no leachate is present in the leachate detection layer and by 0 if leachate is present in this layer.

The landfill design value may therefore be determined as follows:

$$\textbf{Landfill Design Value (LDV)} = \frac{\textbf{Liner Value} \times \textbf{Integrity Value}}{\textbf{Size of the Site}}$$

According to this equation, a 6 ha site designed with a lining system equal to an H:H standard, as specified in the 1998 Minimum Requirements, with no leachate observed in the leachate detection layer, will have a landfill design value of (1500x1)/6, which equals 250.

c) Operational factors

Pollution of ground water, unacceptable odour levels at the site, exposure of workers, etc. are all examples of the effects of poor operation. Although it is difficult to quantify the protection offered by good operation, certain aspects regarding adverse impacts of a site can be related directly to operational factors, and can therefore be used to give an indication of the standard of management at the site, such as:

- The amount of leachate produced. Baldwin (1994) states that this amount, and its impact on the environment is largely determined by the local weather conditions, the management of rainfall on the site and the amount of liquid waste disposed of on the site. It is a Minimum Requirement that no more than 200mm/year of leachate may be generated at a given landfill site. This can be translated to $20m^3/ha$.
- The presence or absence of reclaimers ("scavengers") on the site. When reclaimers is allowed access to a site, the risk to them is increased if a potentially hazardous waste is disposed of on. Currently, it is a Minimum Requirements that no reclaimers are to be allowed onto H:H and H:h landfill sites.
- The buffer zone around the landfill site.

Additional operational factors that can improve the EEPF are:

- The presence of a leachate treatment facility;
- The level of storm water management, as indicated by the quality of storm water leaving the site. If the manager of the site can prove that storm water is successfully diverted around the site, and not contaminated by the activities on the site, this may be taken into consideration when determining the operational value; and
- The achievement of internationally recognised environmental management standards, such as ISO 14001, indicating the level of operation at the site.

The Site's Operational Value can therefore be determined as follows:

Value	100	0.1
Operational aspects		
Leachate generation	Less than 200 mm/year	More than 200 mm/year
On-site leachate treatment	Yes	No
Additional factors		
Scavengers	Absent	Present
Buffer zone	Determined scientifically through air dispersion modelling/ More than 800 m	Less than 800 m
Certified for ISO 14001	Yes	No
Storm water management	No contaminated storm water	Storm water contaminated

d) Monitoring factors

When a landfill site had taken the total load of a specific contaminant, this will be indicated by an increased trend in the concentration of this contaminant in the leachate. Therefore, as part of the determination of the EEPF, regular analysis of the leachate must be conducted to determine increasing trends of specific contaminants, thereby indicating the reduced ability of the waste disposal site to contain such a contaminant. Once such a contaminant have shown this increased trend in the leachate, it disposal of wastes containing this contaminant should be terminated at the specific site.

Using a system such as discussed above, the EEPF for waste disposal on land can be represented numerically, albeit semi-quantitatively. Such a system can be improved continuously with the use of actual measurements and improved knowledge.