Guideline for the management of EDCs in a catchment

Volume V

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The publication of this report emanates from a strategic planning workshop held in Stellenbosch during June 2007 at which the need was identified to develop guidelines in order to provide managers and policy-makers with the background and scientifically relevant information on the EDC phenomena, which would enable them to identify, investigate and develop possible management options for the prevention of EDC pollution in a catchment or smaller area. (Part of WRC Project No. K5/1933)

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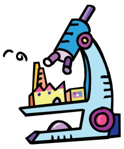
EDC GUIDELINE VOLUMES

The primary purpose of these guideline volumes is to facilitate appropriate water-resource management in South Africa relating to EDCs. They present a consolidation of EDC research, current knowledge and best practices.

Volume I: Introduction (WRC Report No. TT 560/13)

Volume II: Sampling Guide (WRC Report No. TT 561/13)

Volume III: Bioassay Toolkit



Volume IV: Monitoring and Assessment

Volume V: EDC Management in Catchments (WRC Report No. TT 563/13)

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OVERVIEW

Introduction

EDCs comprise a diverse range of mainly man-made chemicals that mimic or antagonise the function of hormones. These chemicals are discharged into the environment through various pathways including ingestion, inhalation and dermal contact. These EDCs may interact with physiological systems and cause alterations in development, growth and reproduction in wildlife and particularly in exposed fish (Jobling and Tyler, 2003). Some of these are persistent in the environment while others are not and some are lipophilic, sequestered in adipose tissue and secreted in milk. Others may only be present for short periods of time but at critical periods of animal development.

Globally, EDC research has been ongoing for the past 20 years. The WRC has funded research into EDCs in water since 1998, participating with the Global Water Research Coalition (GWRC), amongst others, in pro-active research on their effects and implications.

EDCs are not defined on the basis of their chemical nature, but rather by their biological effect. They exhibit agonistic or antagonistic properties depending on the kind of interaction with the receptors. Because oestrogenic receptors are of a similar structure in different animals, including humans, EDCs can affect the endocrine functions of many living species. The main mechanisms through which they interfere with the endocrine system are:

- The simulation of the activities of physiological hormones, thereby participating in the same reactions and causing the same effects.
- The inactivation, with competitive action, of hormone receptors and, consequently the neutralisation of their activity.
- The interference with the synthesis, transport, metabolism and secretion of natural hormones, altering their physiological concentrations and therefore their corresponding endocrine functions.

The definition accepted, from a physiological perspective, by the Endocrine Society (Diamanti-Kandarakis, 2009) and used throughout these EDC guideline volumes is:

> *An endocrine-disrupting substance is a compound, either natural or synthetic, which, through environmental or inappropriate developmental exposures, alters the hormonal and homeostatic systems that enable the organism to communicate with and respond to its environment.*

Catchment context

In a catchment context chemicals are commonplace in all aspects of life. Suspected EDCs can be found in pesticides, fertilisers, pharmaceuticals such as birth control pills, personal care products such as medicines, lotions, cosmetics and sun block, and industrial substances including plasticisers, fabric softeners, fire retardants and cooling agents. EDCs find their way into the environment and water resources via runoff, atmospheric deposition and direct discharges. In this respect every person is in all probability exposed via ingestion, skin contact and breathing to a combination of potential EDCs through various media, on a daily basis.

Although a large proportion of data are available on the occurrence of contaminants such as pesticides, heavy metals, polychlorinated biphenyls (PCB) and polyaromatic hydrocarbons (PAH), the data have been generated for 'water safety' purposes. They are typically assessed against ADI (allowable daily intake) and ERL (environmental risk level) levels. Most of these levels are set for possible carcinogenic effects and not for oestrogenic effects. The oestrogenic effects of some of these compounds may occur at EDC levels up to a million times lower than those producing significant carcinogenic effects (Genthe and Steyn, 2008). Furthermore, because EDC levels producing oestrogenic effects may be at levels below analytical detection limits, measured data can give a false impression.

As a result of this growing concern and the potential global scope of the EDC problem, the possibility of serious problems in humans and wildlife, and the persistence of some suspected EDCs in the environment, research on EDCs is a high priority. Furthermore, a multidisciplinary approach needs to be taken. However, in the interim it is important that strategies are put in place to manage the release of EDCs to the environment, as well as to remove them from raw water prior to distribution to consumers.

While assessment of EDCs in South Africa has been ongoing for many years, the actual situation within South Africa is far from known. Considerable work is therefore still needed to obtain a satisfactory picture of which EDCs can be found where, in what concentrations and what the impacts are on people and the environment. The need for accurate information is fundamental in guiding public health policy decisions and especially in communicating potential impacts to a community.

Management strategies

In this respect the manual highlights matters relating to management strategies. These include the introduction of adaptive management, a naturally sensible framework within which learning can take place. Adaptive management is forward-looking, explicit in its purpose, inclusive, based on co-learning, realistic, action-oriented, flexible, and continually improving. Considering the inherent uncertainties associated with EDCs, adaptive management is seen as an appropriate framework.

An integrated water quality management model (Boyd et al., 2011) is briefly described. The model is based on the premise that good water quality is in everyone's best interests and divides water management into smaller management units while establishing both a horizontal and vertical reporting framework. In addition, while ultimately focusing on raw- and drinking-water quality, the model is linked to land use and the impacts that the land-use activities may have on water quality.

Various non-regulatory options include duty of care, self-regulatory options, and incentive-based regulation. Wastewater risk-abatement planning, support options, best management practices and the precautionary principle are also introduced.

Risk management

The concept of risk is introduced bringing in the concepts of risk perception and acceptable risk. It is highlighted that perception of risk may be very different for different people. In the final analysis, regulatory authorities must respond to the way in which the citizens understand the nature and variety of risks in the environment, how they rank each type of risk in relation to others and how they expect public authorities to manage or control those risks. Acceptable risk is based on the assumption that a small but non-zero probability of an untoward event of some sort occurring exists, below which level the general population is willing, implicitly or explicitly, to accept risk.

Effective risk management requires effective risk assessment: the identification of all potential hazards, their sources and hazardous events, as well as an assessment of the level of risk presented by each, and risk communication. A structured approach is important to ensure that significant issues are not overlooked and that areas of greatest risk are identified. In this respect it is necessary to undertake a pre-screening and prioritisation level assessment in order to prioritise areas of greatest risk for which more detailed assessment would then need to be undertaken. The four main steps proposed for the risk assessment methodology are catchment characterisation, screening for potential EDC contamination, risk mitigation and risk prioritisation.

Risk communication

These are closely linked to how risk is communicated. Public fear of EDCs can be likened to that of radioactivity and disease-causing bacteria and viruses. They are not readily detectable and introduce an additional risk of unknown magnitude that a population has to be protected against. It is vital to communicate the potential risk of EDCs without causing undue fear to the public or manipulation of facts. Even perceived threats to health and environment can be extremely precarious to the survival of the South African economy.

It may easily fall prey to manipulated or spontaneous international actions to ban export products from South Africa due to high levels of one or the other of the identified pollutants (Burger, 2005).

Risk communication is therefore essential. It is a two-way exchange of information about threats, including health threats such as those related to the impacts from endocrine-disrupting chemicals. The goals of risk communication are therefore to enhance knowledge and understanding; build trust and credibility; encourage dialogue; and influence attitudes, decisions and behaviour.

Purpose of the guideline

This guideline volume targets those who regulate or manage natural resources, especially water; land uses that impact on water resources; human health, as well as domestic animal and wildlife health; bulk supplies of safe drinking water; as well as those who inform the above regulators and managers. This guideline has not been compiled for the general public as the detail is quite technical and a more user-friendly document needs to be developed in this regard. It should also be noted that there are different volumes that may be of specific interest to the various researchers working within the EDC field. As such, all volumes may provide insight into the broader topics considered relevant.

The primary objective of this manual for EDC management in catchments is therefore to provide the target audience with a common understanding of the main EDC-related management issues. This manual not only deals with catchment management processes, but is also intended to ensure that information about EDCs can be conveyed to the general public and water users in a consistent, accurate and meaningful manner.

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ABBREVIATIONS

ADI	allowable daily intake
AOP	advanced oxidation processes
API	American Petroleum Institute
BPA	bisphenol A
BPB	bisphenol B
BPF	bisphenol F
CARA	Conservation of Agricultural Resources Act
CCP	critical control point
COD	chemical oxygen demand
CRF	critical risk factor
DDT	1,1,1-trichloro-2,2-bis(chlorodiphenyl)ethane
DES	diethylstilbestrol
DMP	dimethyl phthalate
DWA	Department of Water Affairs
DWQ	drinking-water quality
ED	endocrine disrupting
EDC	endocrine disrupting chemical (also endocrine disrupting compound)
EDM	endocrine disruptive metals
EMS	environmental management system
ERL	environmental risk level
eWQMS	electronic water-quality management system
GAC	granular activated carbon
GMP	good manufacturing practice
GWRC	Global Water Research Coalition
IRS	indoor residual spraying
ISO	International Standards Organization
IWQM	integrated water-quality management
IWRM	integrated water-resource management
MCC	Medicines Control Council
NAWQA	National Ambient Water Quality Assessment (USGS Program)
NDP	National Drug Policy
NEMA	National Environmental Management Act
NOC	N-nitroso compounds

NOEL	no-observed-effect-level
NWA	National Water Act
NWRS	National Water Resources Strategy
PAC	powdered activated carbon
PAH	polyaromatic hydrocarbons
PCB	polychlorinated biphenyls
POE	point of entry
POU	point of use
PPCP	pharmaceuticals and personal care products
REACH	Regulation, Evaluation, Authorisation and Restriction of Chemicals (European Union Regulation of 18 December 2006)
RO	reverse osmosis
RQO	resource quality objectives
RWQO	receiving water quality objectives
SNAEL	suggested no-adverse effect levels
SRT	sludge retention time
TCBPA	tetrachlorobisphenol A
TOC	total organic carbon
US EPA	United States Environmental Protection Agency
UV	ultraviolet
WCW	water care works
WMA	water management area
WHO	World Health Organization
WRC	Water Research Commission
WSA	Water Services Act
WTW	water treatment works
WWTW	wastewater treatment works

GLOSSARY

Endocrine disrupting chemical (EDC)
An endocrine-disrupting substance is a compound, either natural or synthetic, which, through environmental or inappropriate developmental exposures, alters the hormonal and homeostatic systems that enable the organism to communicate with and respond to its environment.

Endocrine system
A control system of ductless endocrine glands that secrete chemical messengers called hormones which circulate within the body via the bloodstream to affect distant organs. It does not include exocrine glands such as salivary glands, sweat glands and glands within the gastrointestinal tract.

Duty of care
The responsibility of those who make, supply, import or use chemicals to provide sufficient information to evaluate risks to health and environment resulting from their manufacture and intended use.

Exposure
Contact between a substance and an individual or a population.

Hazard
An adverse impact on human or environmental health that can result from exposure to a substance.

Point-of-use (POU) treatment unit
This type of unit treats water at a particular tap. It is typically installed on kitchen taps.

Point-of-entry (POE) treatment unit
This unit treats all of the water entering a facility, such as a household or office building, before distribution to the taps.

Risk communication
Risk communication is the act of conveying or transmitting information between interested parties about:

- Levels of health or environmental risks.
- The significance or meaning of health or environmental risks.
- Decisions, actions or policies aimed at managing or controlling health or environmental risks.

Risk
A measure of the hazard to health (or the environment) from exposure to a substance and the probability of its occurrence (the likelihood of a hazardous event occurring).

Perceived risk
An impression or intuitive judgement about the nature and magnitude of a health or environmental risk.

CHAPTER 1

INTRODUCTION

Background

Over the past two decades, considerable attention has been focused on the incidence and risk management of endocrine disrupting chemicals (EDCs). There has been growing concern, public debate and lack of scientific consensus about the potential effects of a number of chemicals that have the potential to alter the normal functioning of the endocrine system (WRC Technical Brief, 11 June 2009).

EDCs comprise a diverse range of mainly man-made chemicals that mimic or antagonise the function of hormones. They are discharged into the environment through various pathways (Figure 1). These EDCs may interact with physiological systems and cause alterations in development, growth and reproduction in wildlife and particularly in exposed fish (Jobling and Tyler, 2003). Some of these are persistent in the environment while others are not and some are lipophilic, sequestered in adipose tissue and secreted in milk. Others may only be present for short periods of time but at critical periods of development.

Globally, EDC research has been ongoing for the past 20 years. The WRC has commissioned and funded research on EDCs in water since 1998, participating with the Global Water Research Coalition (GWRC), amongst others, in pro-active research on their effects and implications.

EDCs are not defined on the basis of their chemical nature, but rather by their biological effects. EDCs exhibit agonistic or antagonistic properties depending on the kind of interaction with the receptors. Because oestrogenic receptors are of a similar structure in different animals, including humans, EDCs can affect the endocrine functions of many living species. The main mechanisms through which they interfere with the endocrine system are:

- The simulation of the activities of physiological hormones, thereby participating in the same reactions and causing the same effects.
- The inactivation, with competitive action, of hormone receptors and, consequently the neutralisation of their activity.
- The interference with the synthesis, transport, metabolism and secretion of natural hormones, altering their physiological concentrations and therefore their corresponding endocrine functions.

As detailed in **Volume IV: Monitoring and Assessment** of these EDC guideline volumes, the definition of an endocrine-disrupting compound has undergone a number of changes. However, the Endocrine Society acknowledged in 2009 that ‘the understanding of the mechanisms by which endocrine disruptors exert their effects has grown', and now recognises much broader mechanisms (Diamanti-Kandarakis, 2009). Thus, in addition to nuclear hormone receptors (e.g. oestrogen and androgen receptors, progesterone receptors, thyroid receptors) effects ‘via nuclear receptors, non-nuclear steroid hormone receptors (e.g. membrane ERs), non-steroid receptors (e.g. neurotransmitter receptors), orphan receptors (e.g. aryl hydrocarbon receptor), enzymatic pathways involved in steroid biosynthesis and/or metabolism, and numerous other mechanisms that converge upon endocrine and reproductive systems’ are also recognised. The definition currently accepted from a physiological perspective is:

> *An endocrine-disrupting substance is a compound, either natural or synthetic, which, through environmental or inappropriate developmental exposures, alters the hormonal and homeostatic systems that enable the organism to communicate with and respond to its environment.*

In a catchment context chemicals are commonplace in all aspects of life. Suspected EDCs can be found in pesticides, fertilisers, pharmaceuticals such as birth-control pills, personal-care products such as medicines, lotions, cosmetics and sun-block sprays and lotions, and industrial substances including plasticisers, fabric softeners, fire retardants and cooling agents. EDCs find their way into the environment and water resources via runoff, atmospheric deposition and direct discharges. In this respect every person is in all probability exposed via ingestion, skin contact and breathing to a combination of potential EDCs through various media, on a daily basis. This is illustrated schematically in Figure 1.

The majority of studies for endocrine disruption in wildlife have come from studying species living in or closely associated with the aquatic environment. These field and laboratory investigations indicate that exposure to EDCs produces adverse effects in some wildlife populations. These range from subtle changes in the physiology and sexual behaviour of species to permanently altered sexual differentiation.

Despite these examples of endocrine disruption in nature, there still remains much debate surrounding the potential effects of EDCs on human health. It is generally assumed, however, that when these chemicals affect animals, they are likely to affect humans as well.

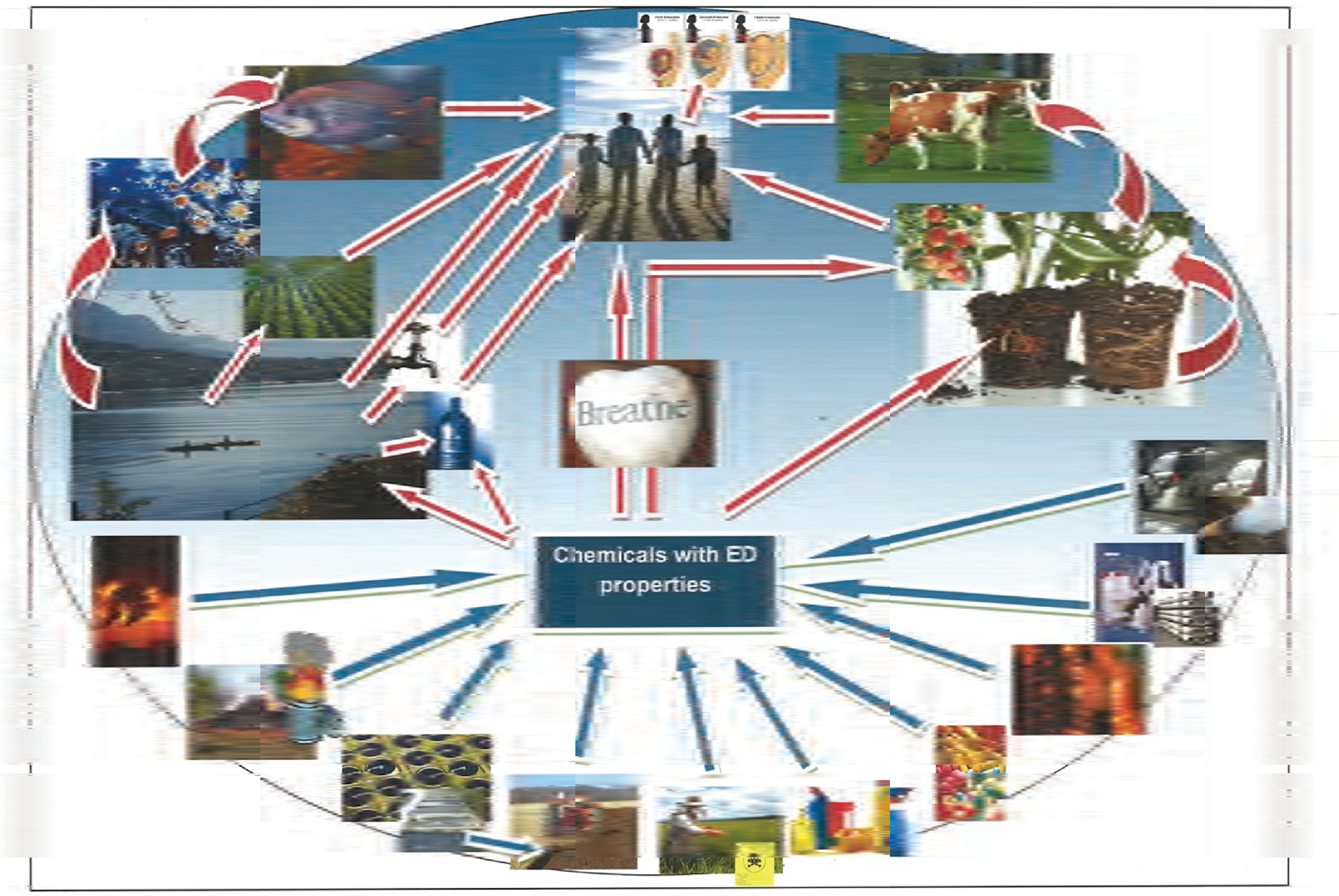


Figure 1: Illustration showing various sources of EDCs and potential pathways

The best defence against these chemical influences is to gain a better understanding of the impacts of EDCs on human development, as well as the presence and effects of EDCs on the environment. This information can then be used by decision-makers to ensure that these chemicals are controlled effectively through legislation to reduce risk of exposure and hence potential environmental and human health impacts.

Although large amounts of data are available on the occurrence of contaminants such as pesticides, heavy metals, polychlorinated biphenyls (PCB) and polyaromatic hydrocarbons (PAH), the data have been generated for 'water safety' purposes. They are typically assessed against ADI (allowable daily intake) and ERL (environmental risk level) levels. Most of these levels are set for possible carcinogenic effects and not for oestrogenic effects. The oestrogenic effect of some of these compounds may occur at EDC levels up to a million times lower than those producing significant carcinogenic effects (Genthe and Steyn, 2008). Furthermore, because EDC levels producing oestrogenic effects may be at concentrations below analytical detection limits, measured data can give a false impression.

As a result of this growing concern and the potential global scope of the EDC problem, the possibility of serious problems in humans and wildlife, and the persistence of some suspected EDCs in the environment, research on EDCs is a high priority. Furthermore, a multidisciplinary approach needs to be taken. However, in the interim it is important that strategies are put in place to manage the release of EDCs to the environment, as well as to remove them from raw water prior to distribution to consumers.

Water-resource managers will need certain questions answered in order to make informed and rational decisions with regards to EDC contamination. **Volume I: Introduction** of the EDC guideline volumes lists some Frequently Asked Questions and fact sheets relating to each of the questions.

Situational assessment of EDCs in South Africa

While assessment of EDCs in South Africa has been ongoing for many years, the actual situation within South Africa is far from known and considerable work is still needed to obtain a satisfactory picture of which EDCs can be found where, in what concentrations and what the impacts are on people and the environment. The need for accurate information is fundamental in guiding public health policy decisions and especially in communicating potential impacts to a community.

In a study undertaken by Burger and Nel in 2008, the results indicated that a large number of pesticides with known endocrine-disruptor properties were registered for use in all the water management areas (WMAs) of the country. There has been considerable focus on EDCs in the Limpopo Province and especially the Luvuvhu/Letaba Water Management Area (WMA) where the pesticide, DDT, has been used annually for malaria control since 1945.

Various studies noted that the following endocrine-disrupting compounds have been detected in South African water resources: pp-DDT, DDE, DDD, endosulfan, endrin, oestrone, oestriol, estradiol, EDMs (endocrine disrupting metals), phthalates, atrazine, p-nonylphenol (p-NP), DEHP, DBP, lindane, chlorpyrifos, polychlorinated biphenyls (PCBs), chlordanes and heptachlor. In most cases, however, the actual concentrations are not known. This is because the analytical procedures to determine the concentrations are expensive and there are very few laboratories in South Africa that can undertake the requisite tests.

Further details of the studies undertaken in South Africa are available in the Literature Review Report available on CD associated with study.

Target audience

This management guideline volume targets the following people:

- Those who regulate or manage:
    - natural resources, especially water
    - land uses that impact on water resources
    - human health, as well as domestic animal and wildlife health
    - bulk supplies of safe drinking water
- Those who inform the above regulators and managers.

This guideline has not been developed for the general public as the detail is quite technical. A more user-friendly document needs to be developed in this regard.

It should also be noted that there are different volumes that may be of specific interest to different researchers working within the EDC field. However, all volumes may provide insight into the broader topics considered relevant. Contact details of where further technical details may be obtained are provided to readers.

Objective

The primary objective of this manual for EDC management in catchments is to provide the above target audience with a common understanding of the main EDC-related management issues. This manual deals not only with catchment management processes but also intends to ensure that information about EDCs can be conveyed to the general public and water users in a consistent, accurate and meaningful manner.

Structure of the guideline

The structure of this guideline is set out below.

Chapter 1: Introduction

This chapter provides a brief background to EDCs, summarises the situation in South Africa, describes the target audience and states the objectives.

Chapter 2: Management strategies

A detailed description of the management approaches that could be used to minimise exposure to EDCs is given in this chapter. It lists relevant legislation and highlights an adaptive management approach. The integrated water-quality management model is also put forward as a risk-reduction mechanism as a component of adaptive management. The precautionary principle is introduced and further management strategies such as duty of care (non-regulatory) as well as self-regulatory and supportive options are briefly discussed.

Chapter 3: Risk management

This chapter delves more deeply into the concept of risk, considering risk perception and acceptable risk. A risk-assessment methodology describes a risk-assessment methodology in four steps and discusses risk communication.

Chapter 4: Risk communication

This chapter sets out the important aspects of risk communication, that simply stated, is the process of informing people about potential hazards to their person, property, or community.

Chapter 5: Rietvlei case study

An example case study based on the Rietvlei Dam catchment is presented in this chapter. The methodology described in the previous chapters of the guideline is used to work through the various steps proposed.

CHAPTER 2
MANAGEMENT STRATEGIES

Legislation

South Africa has some of the best legislation in the world, especially related to the protection of water resources. In many cases the implementation thereof is very poor. The following Acts are relevant to the regulation of EDC management:

- National Environmental Management Act (Act No. 107 of 1998)
- Conservation of Agricultural Resources Act (Act No. 43 of 1983)
- National Health Act (Act No. 61 of 2003)
- Water Services Act (Act No. 108 of 1997)
- National Water Act (Act No. 36 of 1998)
- National Drug Policy for South Africa (1996)
- Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies (Act No. 36 of 1947)
- Foodstuffs, Cosmetics and Disinfectants Act (Act 54 of 1973)
- National Environment Management: Air Quality Act, 2004 (Act 39 of 2004)
- National Environmental Management: Waste Act, 2008 (Act 59 of 2008)

The sections of the Acts relevant to management of EDCs at various levels are summarised in **Volume I** of these EDC guideline volumes and detailed in the Literature Review Report included in the CD. Specific supporting documents such as the South African National Standards for Drinking Water (SANS 241-1 and SANS 241-2: Edition 1, 2011) and the Guidelines for the Utilisation and Disposal of Wastewater Sludge, Volumes 1 to 5 (Snyman and Herselman, 2006) are also described.

Although some of the supporting documents may be considered outdated, the SANS 241 Drinking Water Standards (SANS, 2011) may be used in conjunction with relevant international guidelines.

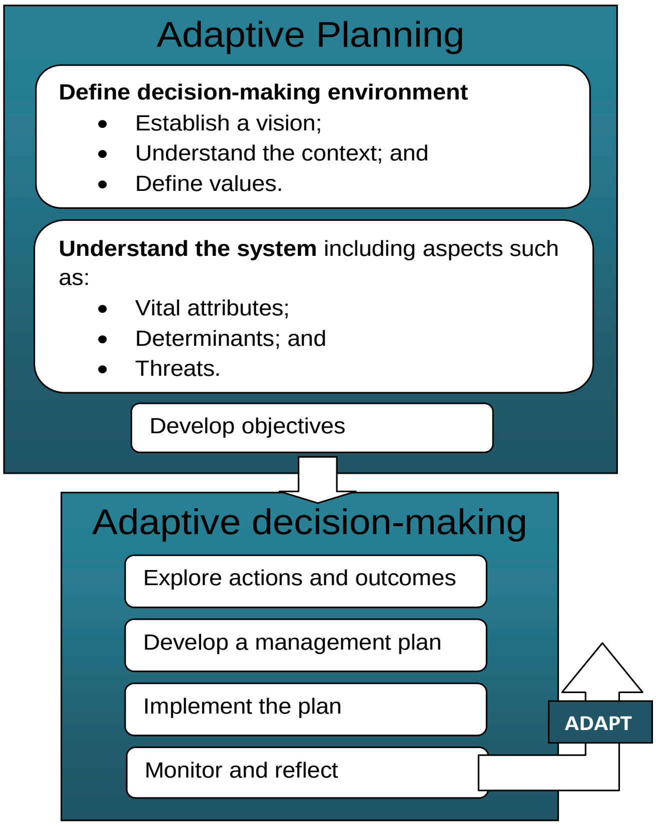
Adaptive management

The move toward accountability in natural resource management has led to a growing need for a more structured approach to decision-making.

Adaptive management is a naturally sensible framework within which learning can take place. By its very nature, it is about learning by doing in a scientific way to deal with uncertainty. It is a structured iterative process of decision-making which guides human interventions in natural ecosystems (Roux et al., 2010).

The approach summarised in Figure 2 acknowledges the inherent uncertainty in the dynamics of ecosystems and that as more is learnt, management can evolve and improve. This is because natural systems are complex and dynamic. The variability in natural systems is therefore unpredictable to some extent. Nonetheless, management decisions need to be made. Adaptive management proceeds despite this uncertainty by treating human interventions in natural systems as large-scale experiments from which more may be learnt, leading to improved management in the future. The inherent uncertainties associated with EDCs makes adaptive management an appropriate framework.

Adaptive management is forward-looking, explicit in its purpose, inclusive, based on co-learning, realistic, action oriented, flexible, and continually improving. Thorough planning precedes adaptive decision-making. This involves consciously predicting and documenting the likely outcome of decisions, while acknowledging the uncertainties. The management plan is then a set of actions with targets. Reflection on monitoring results is done against the targets and predicted outcomes. Future plans, objectives or understanding are then adapted accordingly.



No matter how thorough and complete the initial assessment and design may have been, systems may always respond in ways that may not have been foreseen at the planning stage. Ecosystems exhibit long-term, persistent changes over decades and centuries. In this respect recent experience is not necessarily a good basis for predicting future behaviour. The effects of global climatic change on the dynamics of ecosystems, which are to a large extent unpredictable, will pose many such management challenges. Adaptive management programmes have to include a stage of evaluation and adjustment.

Outcomes of past management decisions must be compared with initial forecasts, models have to be refined to reflect new understanding, and management programmes have to be revised accordingly. New information may suggest new uncertainties and innovative management approaches, leading to another cycle of assessment, design, implementation, and evaluation.

Figure 2: Adaptive management approach (Roux et al., 2010)

Improved clarity about key elements in a decision-making process can help decision-makers focus attention on what, why, and how actions will be taken. Activities in a structured approach to decision-making include:

- Engaging the relevant stakeholders in the decision-making process.
- Identifying the problem to be addressed.
- Specifying objectives and trade-offs that capture the values of stakeholders.
- Identifying the range of decision alternatives from which actions are to be selected.
- Specifying assumptions about resource structures and functions.
- Projecting the consequences of alternative actions;
- Identifying key uncertainties.
- Measuring risk tolerance for potential consequences of decisions.
- Accounting for future impacts of present decisions.
- Accounting for legal guidelines and constraints.

The precautionary principle

The precautionary principle in environmental science is a pro-active approach aimed at avoiding environmental impacts before they occur and reducing risks before they become a reality. For example, it may involve preventing pollution. 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.

Worldwide there is agreement that precautionary action should be taken (Genthe and Steyn, 2009). The precautionary principle is sometimes referred to as ‘prudent avoidance’ where the word prudence means ‘good sense’ (Raffensperger and deFur, 1999).

In terms of EDCs the precautionary approach can be applied in various contexts. It could mean that if the negative effects of EDCs are not yet known or have not yet been proved, the use of these chemicals is then prohibited until proven otherwise (Diamanti-Kandarakis et al., 2009). It could also be that the use of a chemical already being used is addressed. For example, in relation to those EDCs which have already been used and are already in the environment, the precautionary approach would be in relation to monitoring and water use, such as described in Genthe and Steyn, 2008.

The proposed South African health-risk assessment framework for oestrogen activity in treated drinking water (Aneck-Hahn et al., 2009) is consistent with the precautionary principle. It recommends a precautionary risk-based approach whereby a trigger value for endocrine activity is derived. The framework also suggests a tiered approach to screening and testing of chemicals in the water environment rather than testing for specific target chemicals. Should endocrine disruption be detected, then a more detailed assessment using bioassays is recommended.

It is recommended that an approach similar to toxic equivalency factors be considered for hormones and their activity in water and that it be expressed in terms of oestrogen equivalency factors. A value above which a more detailed assessment is recommended would be the ‘trigger value’ (Genthe and Steyn, 2008).

The integrated water quality management model

One approach to risk reduction that could be used in a catchment context is the implementation of the integrated water-quality management (IWQM) model developed through a WRC project (Boyd et al., 2011).

The model is based on the premise that good water quality is in everyone’s best interests and divides water management into smaller management units while establishing both a horizontal and vertical reporting framework. In addition, while ultimately focusing on raw- and drinking-water quality, is linked to land use and the impacts that the land-use activities may have on water quality. Three main components are important to understanding the IWQM model:

- *Defining principles*: These are generalisations that are accepted as true and that can be used as a basis for reasoning or conduct, such as, water must be properly valued (because there is not enough water).
- *Background conditions:* These are conditions external to water quality which support the implementation of this framework and therefore indirectly impact on water quality, such as management systems and tools.
- *Management units:* A unit is a geographical area that could be managed as a whole because of common water-use characteristics at the ‘lower’ levels and institutional responsibilities relating to management of water quality at the ‘higher’ levels.

The ultimate goal of IWQM is to achieve specific objectives at a particular management unit taking into consideration the defining principles and background conditions relevant to that specific management unit. There are, however, specific elements that must be included for each management unit:

- Identification of the components of the water-use cycle elements which equates to the catchment characterisation (*Step 1* in **Chapter 3**).
- Hazard/risk assessment in which critical risk factors (CRF), critical control points (CCP) and performance targets are set.
- Risk management.
- Contingency planning: what is or will be put in place if a performance target is not met.

A critical control point (CCP) is defined as a point or process that requires technical target measures or parameter ranges to be met in order to continually assess the hazard potential of the water resource. The CCP is most often defined by regulatory controls. For example, it could be a condition in a water-use authorisation in terms of the National Water Act (Act 36 of 1998). A point includes a discharge point; a point in a stormwater system; or a point in a water resource; and a process may be a procedure or practice, such as optimal fertiliser application rate; dam-water levels measured; or buffer strips in place.

A critical risk factor (CRF) is defined as a point or process at which, if a failure occurs, the CCP performance targets will not be met. In other words, the CRFs are upstream of the CCPs and would also have performance targets linked to them. However, these are internal targets (targets set by the management unit itself) that if achieved would mean that that the CCP targets would be met. These may be, for example, pumping hours met to avoid overflows or process samples taken to ensure that adequate chemicals are added for phosphate removal.

It is the implementation of these CCPs and CRFs and their associated performance targets that bring in the safeguards to reduce the risk of EDCs being released to the environment.

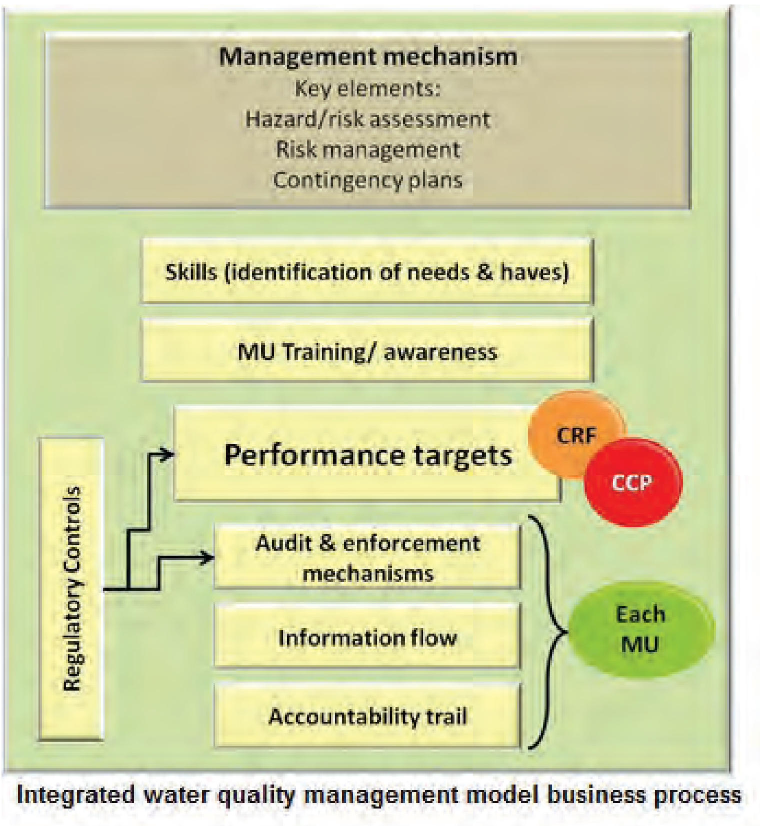


Figure 3: Integrated water-quality management model business process (Boyd et al., 2011)

The business process (Figure 3) for the IWQM conceptual model is generic in the sense that its various elements apply at every 'level' of management, or rather, to every management unit. Therefore each aspect must be in place in every management unit although the details of each element will vary according to the management unit. It is important to note here that the model allows for linkages with existing tools, such as the DWA Water Management System (WMS) and the electronic Water Quality Management System (eWQMS) and any other systems that an institution may already have in place.

A major benefit of the model is that responsibility for water quality is based on significantly smaller geographical areas. Accountability to the adjoining areas (horizontal accountability) and to the next level of management (vertical accountability) is established when the management unit is established.

This allows accountability for water quality to be focused on smaller management units, rather than diffused up to ever higher levels of management. In other words, all water users are made aware of their own responsibility for the protection of South Africa's water resources and are accountable for the impacts that they have on the resource. It is this mutual understanding between water users of the impacts of their own uses which is aimed at bringing to life the philosophy 'Everyone is downstream' and 'Every water user is a water manager'.

Non-regulatory

Duty of care

Definitions: **Duty of care** *n.* a requirement that a person act toward others and the public with watchfulness, attention, caution and prudence that a reasonable person in the circumstances would. If a person's actions do not meet this standard of care, then the acts are considered negligent, and any damages resulting may be claimed in a lawsuit for negligence (http://www.duhaime.org/LegalDictionary/D/DutyofCare.aspx)

an obligation to conform to a certain standard of conduct for the protection of another against an unreasonable risk of harm (http://www.duhaime.org/LegalDictionary/D/DutyofCare.aspx)

In tort law, a duty of care is a legal obligation imposed on an individual requiring that they adhere to a standard of reasonable care while performing any acts that could foreseeably harm others.

In essence, the question needs to be asked: who should do what and when? In a catchment situation there are many 'Who's' all of whom need to be doing something at some time to protect the environment.

The guideline discusses risk management, setting out a methodology to undertake risk assessment. Each of the components identified in the catchment-characterisation process set out in *Step 1* in **Chapter 3** may be a 'Who' that must undertake something at some time. In other words, each producer of EDCs, whether directly or indirectly, has a duty of care towards the environment and the health of the population that they may impact on. This principle is one that will require some kind of change management.

Self-regulatory options

There are various self-regulatory options such as ISO 14000 and ISO 14001. ISO 14000 is a series of environmental management standards for organisations developed and published by the International Organization for Standardization (ISO). The ISO 14000 standards provide a guideline or framework for organisations that need to standardise and improve their environmental management efforts. The ISO 14000 standards are not designed to aid the enforcement of environmental laws and do not regulate the environmental activities of organisations. Adherence to these standards is voluntary.

The ISO 14001 standard is the most important standard within the ISO 14000 series. ISO 14001 specifies the requirements of an environmental management system (EMS) for small to large organisations. An EMS is a systematic approach to handling environmental issues within an organisation. The ISO 14001 standard is based on the Plan-Check-Do-Review-Improve cycle (Figure 4).

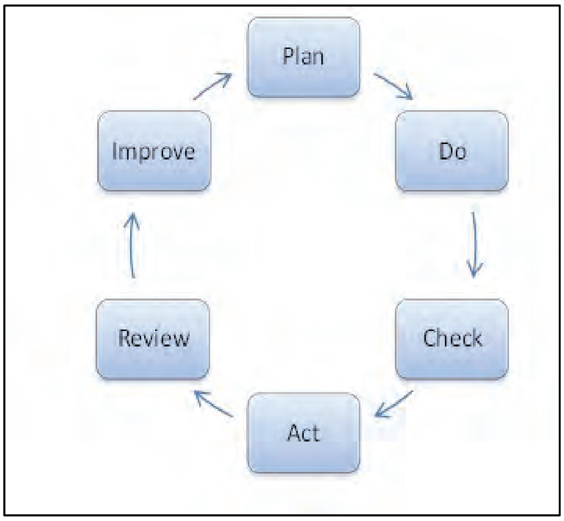


Figure 4: The ISO14001 Plan-Check-Do-Review-Improve

The **Plan** component deals with the beginning stages of an organisation becoming ISO 14001-compliant. The **Check** cycle deals with checking and correcting errors. The **Do** cycle is the implementation and operation of the ISO 14001 standard within an organisation. The **Review** cycle is a review of the entire process by the organisation's top management. And the **Improve** cycle is a cycle that never ends as an organisation continually finds ways to improve their EMS.

The entire process may take several months to several years to complete depending on the size of the organisation. If an organisation is already ISO 9000-certified, the implementation of ISO 14001 does not take as long. When an organisation is compliant, they can either register with a third-party registrar or self-declare their compliance. The ISO 14001 standard is the only ISO 14000 Standard that allows an organisation to be registered or 'certified'.

Incentive-based regulation

Blue Drop and Green Drop Certification

One of the regulatory approaches gaining momentum in South Africa is that of incentive-based regulation which was introduced by DWA in September 2008. It is defined by two programmes: the Blue Drop Certification Programme for drinking-water quality and Green Drop Certification Programme for wastewater quality management regulation.

The objectives of the Blue Drop Certification Programme are to:

- Introduce incentive-based regulation of the drinking-water quality management function.
- Introduce key requirements for effective and efficient management of drinking-water quality by water service institutions.
- Initiate transparency on the actual drinking-water quality management performance of water service institutions.
- Provide information to the public on drinking-water quality performance per water supply system (to prevent generalisation).
- Facilitate closer working relationships between water service authorities and water service providers (where relevant).

It is a legislative requirement that water service institutions have suitable monitoring programmes in place and this would include compliance monitoring. The Drinking Water Quality Regulation Programme identified a significant limitation in an approach which depends upon compliance monitoring only, since ensuring the safety of tap water requires proactive preventative management. The introduction of the certification programme ensures that the South African water services sector adopts the required preventative approach towards the management and regulation of drinking water. Compliance monitoring remains an integral part of DWQ management, however, with the key purpose of gauging the efficacy of the manner in which the quality of tap water is being managed (Blue Drop Report, 2011).

The Green Drop Certification Programme seeks to identify and develop the core competencies required for the sector that if strengthened, will gradually and sustainably improve the level of wastewater management in South Africa. This form of incentive- and risk-based regulation intends to synergise with the current goodwill exhibited by municipalities and existing Government support programmes to give the focus, commitment and planning needed.

Regulation is important to ensure effective and efficient delivery of sustainable water services. This is recognised both by South African authorities and internationally. It clarifies the requirements and obligations placed on water service institutions, thereby protecting consumers from a potentially unsustainable and unsafe service (Green Drop Report, 2011).

While the Green Drop assessment focuses on the entire business of the municipal wastewater services (entire value chain), the risk analysis focuses on the wastewater treatment function specifically. This allows the Regulator to have insight into the treatment component of the municipal business, which is one of the high risk components within the production chain. Risk-based regulation allows the municipality to identify and prioritise the critical risk areas within its wastewater treatment process and to take corrective measures to abate these. Risk analysis is used by the Regulator to identify, quantify and manage the corresponding risks according to their potential impact on the water resource and to ensure a prioritised and targeted regulation of high-risk municipalities (Green Drop Report, 2011).

Wastewater risk-abatement planning (W_2RAP)

Wastewater treatment is the first barrier in a multi-barrier system of ensuring public and environmental health. The W_2RAP identifies, plans and manages risks in the wastewater collection and treatment system in the same way that the Water Safety Plan identifies, plans and manages the risks in the drinking-water treatment and supply systems. .
The development of the South African W2RAP Guideline for Municipalities draws from the principles and concepts of other risk-management procedures, such as the Water Safety Plan and Hazard Analysis and Critical Control Points. The Guideline is published by the Water Research Commission and the Department of Water Affairs. Municipal W2RAPs will be invited as part of the Portfolio of Evidence in future Green Drop assessments and will enjoy increased weight to encourage municipalities to use risk abatement in their business decision-making processes. It also encourages methodical thinking, as well as a more proactive and pragmatic approach towards improved wastewater service management (DWA, 2010).

Support options

In order to be successful, all programmes require support in the form of research and development, awareness, training and funding. This may be done through government departments or privately through industry, especially where an industry has identified a problem and needs to do further assessment of any associated risks.

Best management practices

Water, soil and air are typically the prime media impacted by human activities. In the ideal world, pro-active management would be put in place from the outset of these activities limiting contaminants to the environment. However, in the real world this does not always happen. In most cases, if good or best practice was to be put in place in areas where potential EDCs are produced, discharged or released to the atmosphere, then EDCs in the environment could be limited.

Potable water treatment

For the treatment of potable water, granular activated carbon (GAC) is the best available technology for the removal of all or many EDCs. However, other technologies such as coagulation/filtration and lime softening, used in the multistep process of treating water to potable quality, enhance its' performance (Minnesota Wastewater Treatment Best Practices, 2011.

When considering operating costs of GAC, these depend heavily on various issues such as: quantity and nature of organic compounds present in the raw water; the type of carbon employed; rate of carbon exhaustion; frequency and efficiency of regeneration; and process losses. Usually pilot-plant trials (several months long) have to be undertaken on the specific water source to be treated in order to estimate these variables. Even then, predicted operational parameters may differ significantly upon plant scale-up.

Reverse osmosis (RO) appears to be a viable treatment for the removal of most EDCs and pharmaceuticals and personal-care products (PPCP) in drinking water, except for neutral low-molecular-weight compounds. Reverse osmosis achieved >90% removal of natural steroid hormones in one study. A combination of reverse osmosis with nanofiltration can result in very efficient PPCP removal, including a wide range of pesticides, alkyl phthalates, and oestrogens (Minnesota Wastewater Treatment Best Practices, 2011).

In some cases, ozonation has been very effective in removing pharmaceuticals: diclofenac and carbamazepine (>90%) and bezafibrate (50%). Clofibric acid was stable even at high ozone doses. Ethinyl estradiol and estradiol are expected to be completely transformed and nonylphenols have also been effectively removed. However, pairing ozonation with UV or H_2O_2 (peroxide, such as is done in advanced oxidation processes) may be required to achieve the most effective transformation of pollutants. For example, ozonation alone did not remove clofibric acid, but when pairing O_3 with H_2O_2, improved removal of clofibric acid and other compounds was achieved (Minnesota Wastewater Treatment Best Practices, 2011).

Domestic wastewater treatment

Natural oestrogens have been noted to make up the majority of wastewater effluent oestrogenicity (Minnesota Wastewater Treatment Best Practices, 2011). Activated sludge processes have been shown to remove more than 77% and 90%, respectively, of the natural oestrogen compounds, oestrone and estradiol across all biological field treatment types (Minnesota Wastewater Treatment Best Practices, 2011). Another study reports that activated sludge can consistently remove more than 85% of estradiol, oestriol, and ethinyl estradiol (synthetic oestrogen used for birth control pills), while oestrone is more variable.

Natural estrogens tend to be low on the sorption spectrum, and thus most of their removal is due to biodegradation and not simple sorption, although oestrogenic activity is still expected in the resultant sludge. Maximum removal of natural estrogens occurs in aerobic conditions; in anaerobic conditions, some compounds such as oestrone are more persistent and degradation decreases by a factor of 3 to 5. Ethinyl estradiol is only degraded under aerobic conditions, while estradiol is oxidised at similarly high rates across all redox conditions.

Estradiol removal efficiencies in a Canadian study of 16 WWTWs found estradiol removal rates to be in the order of 40% to 99%, and oestrone removal rates from net production of 98%. Nitrification has been correlated with successful oestrone and estradiol removal. Estradiol is noted to require similar conditions as those that result in nitrification.

In general, removal of oestrogenic activity is highly variable during conventional secondary treatment. Natural steroid oestrogens degrade slowly (in order of rapidity: oestrone>estradiol>ethinyl estradiol, with complete removal of ethinyl estradiol taking up to a few days).

Overall, some estradiol and oestrone are expected to persist following conventional activated sludge treatment, with relatively lower estradiol persistence (<10%). Cited studies show estradiol removal rates of 70%, 87%, 88%; oestrone rates of 74% and 61%; oestriol rates of 80% to 95%; and ethinyl estradiol rates of 30% to 85%. Assessment of natural oestrogen removal is complicated by the possibility that these compounds are being transformed into their different chemical forms inside the WWTW. A full-scale mass balance showed that total oestrogenic potential was reduced from between 58 ng/ℓ and 70 ng/ℓ to 6 ng/ℓ in one WWTW, where conventional activated sludge treatment was used. Another study reported 50% to 66% total oestrogenic potential reduction in conventional activated sludge treatment, with 5% to 10% of the total oestrogenic potential partitioning to sludge.

WWTWs using activated sludge with nitrification/denitrification processes have been shown to have increased removal of PPCPs, EDCs, and nitrate compared to WWTWs without nitrification/denitrification. Many studies have confirmed that more than 90% of oestrone, estradiol, and ethinyl estradiol will be removed from activated sludge treatment plants with nitrification/denitrification. Sludge age (same as solids retention time), hydraulic retention time, temperature, nitrification/denitrification, and phosphate elimination are thought to be factors affecting removal rates of contaminants in activated sludge systems.

Regarding synthetic EDCs and PPCPs; alkylphenols (non-ionic detergent surfactant additives and their stable breakdown products which can constitute up to 5% to 10% of dissolved organic carbon in the raw sewage) are less soluble in water and tend to accumulate more in sludge than the natural estrogens. These chemicals tend to persist in anaerobic sludge environments, although subsequent land distribution may result in more than 90% degradation over a one to three month period. Additionally, nonylphenol (NP) has been detected in surface water receiving WWTW effluent in the 0.1 µg/ℓ to14 µg/ℓ range, indicating that not all nonylphenol is bound to sludge; significant portions remain in the effluent.

In a study of 5 conventional activated sludge WWTWs, 85% to 99% of nonylphenol and 38% to 99% bisphenol A (BPA) were removed. Alkylphenols and phthalates concentrated in sludges. Nonylphenol has shown indications of being degradable by conventional activated sludge similar to other major wastewater organic compounds (60% to 88% removal rate), although widely varying ranges have been reported. Again, where nitrification occurs, removal of nonylphenol tends to be enhanced. Additionally, production of oestrogenic by-products is reduced in aerobic vs. anaerobic sludges.

In one published study, 95% of ibuprofen was removed, in agreement with other findings reported in the literature stating that ibuprofen, although widely present, can be readily eliminated. ‘Low’ eliminations of atenolol, sotalol, trimethoprim, azithromycin, erythromycin, macrolide antimicrobials, and ‘variable’ eliminations of sulphamethoxazole and ketoprofen were reported in WWTWs using activated sludge.

It is important to note that although conventional WWTWs can achieve high removal efficiencies this treatment does not eliminate trace PPCP contamination in surface waters, as removal rates vary greatly due to local conditions and the nature of the contaminant. Linear alkylbenzene sulphonates (LAS) are used in the production of anionic surfactants; they are readily biodegraded in conventional WWTW settings (approximately 80% biodegradation, with total removal of 95% to 99.5%). Phthalate plasticisers and brominated flame retardants tend to partition to sludge in the WWTW process.

In summary, overall removal rates of EDCs and PPCPs in conventional WWTWs with activated sludge vary strongly, and elimination is often incomplete. The more polar the molecule, the more likely it is to remain soluble in effluent. Activated sludge processes can result in high EDC removal, but are not likely to achieve concentrations below maximum allowable levels for some oestrogens, alkylphenols, or BPA (Minnesota Wastewater Treatment Best Practices, 2011).

Industrial wastewater treatment

Industrial effluents emanate from many industries, including:

- iron and steel industry
- mines and quarries
- food industry
- complex organic chemicals industry

All of these produce known EDCs in some form and can reach the environment via direct discharge or spillage to a water resource, indirectly through disposal to sewer or through infiltration from ponds to groundwater. Various treatment processes are therefore needed to remove the contaminants. Processes include simple sedimentation techniques for solids removal; filtration or even ultrafiltration for very fine solids; flocculation; and skimming devices for removal of oil, grease and other hydrocarbons from water.

Wastewater from large-scale industries such as oil refineries, petrochemical plants, chemical plants and natural gas processing plants commonly contain large amounts of oil and suspended solids. Many of these industries use a device known as an API oil-water separator (designed according to standards published by the American Petroleum Institute), designed to separate the oil and suspended solids from the effluents. The effluent is then sent for further treatment which usually consists of an electro-flotation module for additional removal of any residual oil and then to some type of biological treatment unit for the removal of undesirable dissolved chemical compounds.

Another option is parallel plate separators which are similar to API separators but include tilted parallel plate assemblies (also known as parallel packs).

Biodegradable organic material of plant or animal origin can in most cases be treated using extended conventional wastewater treatment processes such as activated sludge or trickling filter. However, problems can arise if the wastewater is excessively diluted with washing water or is highly concentrated such as neat blood or milk. In addition, the presence of cleaning agents, disinfectants, pesticides or antibiotics can have a detrimental impact on such biological treatment processes.

Synthetic organic materials such as solvents, paints, pharmaceuticals, pesticides and coking products can be very difficult to treat. Treatment methods are often specific to the material being treated and include: advanced oxidation processes (AOP), distillation, adsorption, vitrification (supercooling a viscous liquid into the glass state), incineration, chemical immobilisation or landfill disposal.

Acids and alkalis can in most cases be neutralised under controlled conditions. However, neutralisation frequently produces a precipitate that will require treatment as a solid residue and may also be toxic. In a number of cases, gases may be evolved requiring treatment for the gas stream. Therefore some other form of treatment is usually required following neutralisation.

Toxic materials including many organic materials, metals (such as zinc, silver, cadmium, and thallium) acids, alkalis, non-metallic elements (such as arsenic or selenium) are generally resistant to biological processes unless very dilute. Metals may be precipitated out by changing the pH or by treatment with other chemicals. Many, however, are resistant to treatment or mitigation and may require concentration followed by land-filling or recycling.

The activated sludge process can treat any biodegradable organic material in solution or in suspension in wastewater. Apart from domestic wastewater, which is highly biodegradable, many other industrial wastes can also be treated using this process. These wastewaters include effluents from pulp and paper mills, food industries, abattoirs, textile mills, edible oils, coal-gasification wastes, biodegradable pharmaceutical and petrochemical wastes and even some oil-refinery wastes (WISA, 2002).

Diano and Mita (2011) note that for water treatment in relation to ecosystems, the traditional membrane-based processes such as ultrafiltration and reverse osmosis, known to remove EDCs, are not necessarily the best when returning water to an ecosystem as the salts and bio-elements necessary for life are also removed. The selective removal of endocrine disruptors by enzyme treatment (bioremediation) appears more suitable as the treatment targets specific contaminants.

CHAPTER 3
RISK MANAGEMENT

The nature of risk

Risk is a concept that denotes the probability of a specific outcome. In other words, risk is the likelihood/probability of a hazard/hazardous event occurring and it having an impact on a receptor.

Risk is therefore a function of *hazard* and *exposure*:

- *Hazard*: an adverse impact on human and/or environmental health that can result from exposure to a substance such as a biological, chemical, physical or radiological agent that has the potential to cause harm
- *Exposure:* the contact between a substance and an individual or a population.

Technically, the concept of risk is independent of the concept of value; and as such, eventualities may have either beneficial or adverse results. However, in general usage, the convention is to focus only on potential negative impact to some characteristic of value that may arise from a future event. For practical purposes all activities undertaken imply some risk to human or animal health or the environment.

In order to decrease the risk of potential adverse health effects associated with the presence of EDCs in South Africa's raw and drinking-water resources, two basic strategies should be in place:

- Protect source waters from contamination by EDCs (the agent).
- Remove EDCs (the agent), which may be present in source waters, during the drinking-water treatment process.

When considering each case, it is therefore important to undertake an assessment of what is a tolerable risk, considering both the benefits likely to be realised, as well as the hazards. Adherence to the concepts of sustainable development and the precautionary principle will influence such assessments.

Risk analysis includes the processes of risk assessment and risk management. Assessment processes include identification, description and measurement of features such as toxicity, exposure and pathways in relation to population at risk as well as considerations of average and cumulative risk. Risk-management processes then include the processes of evaluation and judgment, decision-making in relation to acceptable risk, priority of concern and economic considerations, and implementation of actions which would include risk communication.

Approaches to managing risk are:

- removing or controlling the use of the agent
- removing or controlling release of the agent to the environment
- removing or controlling exposure to the agent

WWTWs, smokestack scrubbers, and other 'end-of-pipe' control systems are examples of the second approach. The second approach is usually taken by pollution prevention and 'sustainability' advocates. The third approach of using physical or behavioural barriers has been traditionally taken when the first two are impractical, such as in the case of reducing the risks of skin cancer for example, where controlling the sun has proven difficult. Unlike the first two approaches, where technology can be used as a solution, the problem of reducing exposures often relies on influencing human behaviour. The solution then is providing risk information to the public in such a compelling way as to result in reductions in the exposures to agents of morbidity, mortality or injury.

Risk analysis as part of risk management is the evaluation and ranking of potential hazards based on estimated frequency and intensity, and then determining a margin of safety. In other words, risk analysis must include:

- an event
- the probability that the event will occur
- the impact it will have if it happens

At this stage it is very important that the distinction between hazard and risk is understood so that attention and resources can be directed to actions based primarily on the level of risk rather than just the existence of a hazard. The following example helps to clarify this way of perceiving risk. However, it can also be as a result of a series of events (for which there is an associated frequency).

The protozoan parasite *Cryptosporidium parvum* is a hazard. Failure at a water-treatment plant leading to *C. parvum* passing into the distribution system is a hazardous event. The likelihood of the organism being present in source water and passing through the treatment plant in sufficient numbers to cause illness is a risk. In other words, risk is the likelihood/probability of a hazard/hazardous event occurring and it having an impact on a receptor.

Practically, managing risk means making choices, often on highly complex matters. There are often widely differing judgements on what levels of risk are acceptable and on who is entitled to make the call. All parties must also make choices about how to balance estimated health and environmental risk against the estimated economic and social benefits to be derived from using toxic chemicals, in full knowledge of the likelihood that new information accumulated in the future will show that certain earlier choices were incorrect.

In this respect the 'chance of loss' and the 'expectation of net benefit' are inescapably linked in risk activity. MacCrimmon and Wehrung (1986) identified three basic determinants of risk:

- lack of control (natural/human)
- lack of information
- lack of time

These three determinants are interrelated and compound each other. Lack of control, regardless of whether it is natural or human, can stem from insufficient resources or lack of information or lack of time. Lack of information can be caused by inadequate or unreliable data and also lack of time. Lack of time is simply a reflection that we must make a choice before an uncertain event plays itself out. MacCrimmon and Wehrung (1986) then suggest these determinants of risk against the well-known components of risk:

- the magnitude of potential loss
- the chances of potential loss
- the exposure to potential loss

In this context risk is a measure of both the hazard to health (and the environment) from exposure to a substance and the probability of its occurrence in the environment (Leiss and Chociolko, 1994).

Risk perception

Perception of risk may be very different for different people. In the final analysis, regulatory authorities must respond to the way in which the citizens understand the nature and variety of risks in the environment, how they rank each type of risk in relation to others and how they expect public authorities to manage or control those risks. This is closely linked to how risk is communicated, which is dealt with in **Chapter 4: Risk communication**.

Perceived risk has been defined as an impression or intuitive judgement about the nature and magnitude of a health risk (Leiss and Chociolko, 1994). Perceptions of risk involve the judgements that are made when populations are asked to characterise and evaluate hazardous substances and activities.

Three main factors have been shown to influence perceived risk:

- degree to which the hazard is understood
- degree to which it involves feelings of dread (including fatalities)
- size and type of the population at risk (especially if children are singled out)

Despite these difficulties in assessing risk, people may use existing information to form strong views about risks, and such perceptions are often resistant to change. This can lead to a situation where new evidence that is consistent with initial perceptions is accepted, while that which is contrary is dismissed.

It must also be considered that most people do not perceive all lives to be of equal value, nor do they perceive all forms of death as equal. Frequently non-fatal health impairment such as permanent brain damage is seen as more serious than death itself. Often in the public's view the significance of an events' probability tends to decrease as conceivable consequences increase, until what is possible becomes more feared than what is probable. This highlights the importance of timeous and relevant risk communication.

It has also been suggested that 'the controversies over chemical risks in our society may be fuelled as much by weaknesses in the science of risk assessment as by micro-conceptions of the public' (Kraus et al., 1992).

Acceptable risk

The concept of acceptable risk is based on the assumption that a small but non-zero probability of an untoward event of some sort occurring exists, below which level the general population is willing, implicitly or explicitly, to accept risk. However, all of the following conditions need to be met for a level of risk to be judged acceptable:

- The level of risk is itself below some threshold (for example, NOEL – no observable effect level), or on a risk-risk comparison a risk is incurred to avoid another risk of greater magnitude.
- Benefits clearly *appear* to outweigh risks, ultimately just on the intuitive level (for example: our industry needs to use this risky product or process in order to remain competitive in world markets).
- There is no manifestly unjust distribution of risks and benefits, in particular, the lives or health of some specific and identifiable individuals are not being sacrificed in the name of the 'general good'.

Risk assessment methodology

Effective risk management requires effective risk assessment: the identification of all potential hazards, their sources and hazardous events, as well as an assessment of the level of risk presented by each, and risk communication. A structured approach is important to ensure that significant issues are not overlooked and that areas of greatest risk are identified. In this respect it is necessary to undertake a pre-screening and prioritisation level assessment in order to prioritise areas of greatest risk for which more detailed assessment would then need to be undertaken.

Realistic expectations for hazard identification and risk assessment are important. In most cases information/knowledge is inadequate to complete a detailed quantitative risk assessment. Hazard identification and risk assessment are predictive activities that often lead to subjective findings containing uncertainty. These inherent limitations must be recognised so that effective responses can be provided when events differ from predictions. A realistic perspective on the limitations of these predictions should be understood so that the correct message is conveyed to the public. This is why an adaptive management mindset, described briefly in **Chapter 2** under *Adaptive management*, is so important.

A consistent methodology must be established for both hazard identification and risk assessment, and the methodology needs to be transparent and fully understood by everyone involved in the process.

It should be noted that although the focus may often be on investigating suspected EDCs from anthropogenic sources, a description of baseline conditions for naturally occurring anomalies that may directly or indirectly influence EDC effects, is a fundamental requirement. It is also critical in terms of decision-making to be able to place potential EDC effects within the context of other adverse effects due to toxicological and/or carcinogenic risks. The latter is regarded as being better described with water-quality guidelines offering insight into key considerations regarding water quality and fitness for its intended use.

The critical approach to addressing sources, pathways and receptors (the Source-Pathway-Receptor (S-P-R) Model) allows for a range of key information types to be described. This may affect the management decisions regarding the acceptable risk levels appropriate, for example sensitive user types (receptors).

Step 1: Catchment characterisation

It is important to acknowledge up front that catchment management within the South African context is based on the concept of integrated water-resource management (IWRM). This entails complex socio-economic and socio-ecological processes that require vigorous communication between the stakeholder groups including regulators and water users who use water as defined by Section 21 of the NWA, consumptively and non-consumptively. Water use in this context is inextricably linked to land use so that IWRM becomes a complex interaction of land use, human behaviour, water quality and quantity. In this respect any potential pollution source should be considered when characterising the catchment and the methodology followed for EDCs should be relevant to all.

In characterising the catchment, answers to questions relating to groundwater and surface-water migration potential, surface soil migration potential, and human and ecological exposure to EDCs, and in the context of IWRM, all other contaminants, will help the manager make a decision on the risks posed by various sites within the catchment (Tables 1 and 2).

Catchment activities would include point-source discharges such as human and industrial waste discharge, as well as diffuse sources such as those arising from agricultural and intensive animal feedlot activities. Continuous, intermittent or seasonal pollution patterns should also be considered, as well as extreme and infrequent events such as droughts or floods. The water-use cycle depicted in Figure 5 (Boyd et al., 2011) could be used as a basis to identify all the consumptive and non-consumptive water uses, different types of water users such as domestic, industrial and agricultural; and importantly, land-use types. The inclusion of precipitation as a consumptive use highlights the importance of collection, storage and use of rainwater. The eco-regions should also be identified as this would have potential for the use of pesticides to control diseases such as malaria.

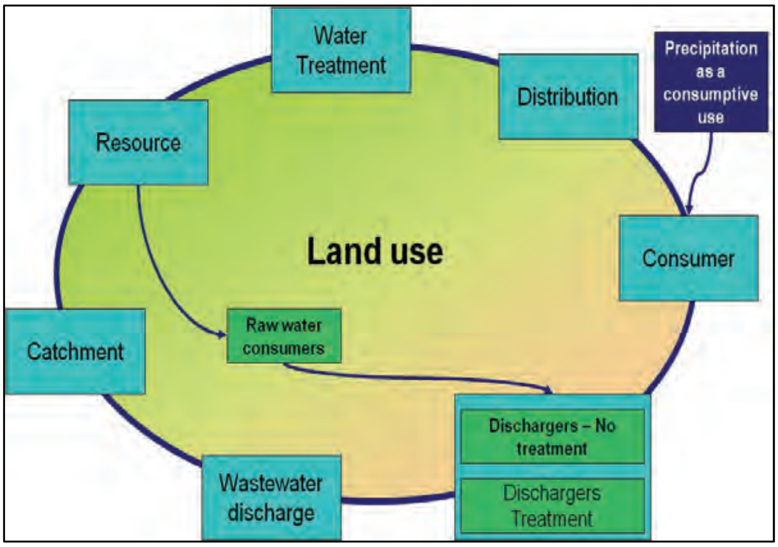


Figure 5: Water-use cycle (Boyd et al., 2011)

The first step in characterising the catchment will be the identification of land use and associated water uses. For example:

- Agriculture: raw-water abstraction and irrigation.

- Urban: abstraction, treatment for potable supply and discharge of treated domestic effluent.

Step 2: Screening for potential EDC contamination

Essentially a simple pre-screening hazard/hazardous event identification should then be undertaken on each of the land-use types identified to enable certain sites to be either taken forward for prioritisation for further EDC assessment or removed and not considered further. If the site is unlikely to be a major source of EDC contamination (directly or indirectly) there is no reason to continue with the prioritisation in relation to EDC contamination. Historical analytical data in this respect would be useful, but is not essential. Where data are available, they will be useful in acknowledging a pollution problem. However, it is important to note that:

- In most cases analytical data on EDCs will be limited to non-existent.
- Acceptable effluent quality (in terms of compliance to water-use authorisation limit values or resource water-quality objectives) does not necessarily mean that EDCs are absent; although it is likely, though not always the case, that the concentrations of EDCs would be lower in a good quality effluent than in a poor quality effluent.
- Poor quality effluent does not necessarily indicate the presence of EDCs.

Based on the catchment characterisation, potential hazards and hazardous events related to each of the land-use types would be identified. The hazard identification and risk assessment should be reviewed and updated periodically because changing conditions may introduce important new hazards or modify risks associated with hazards already identified.

The characteristics set out in Table 1 could be used to assess the likelihood of environmental damage in a catchment. It is important to note that naturally occurring EDCs should also be determined in order to gain some perspective on the risk posed by contaminants.

Table 1: Characteristics (E1-E16) that could be used to assess the likelihood of environmental damage in a catchment

No	Characteristic	Reason for considering
E1	Period of EDC use/production at the site or presence of naturally occurring EDCs	The longer the contaminants are used at the site, or the presence of naturally occurring EDCs, the greater the likelihood that the site is either directly or indirectly contaminating the environment.
E2	Average rainfall and the slope of site	The steeper the gradient, the greater the potential for runoff and erosion and therefore surface water transporting contaminants which were originally in soils.
E3	Ongoing activities resulting in chemical contamination	If activities resulting in chemical contamination are ongoing, then there is a greater ongoing likelihood that humans, other animals or the environment are being exposed.
E4	Soil contaminant concentrations (known or strongly suspected) and type of soil	Coarser soils allow for more infiltration of water and therefore less runoff. Measured concentrations of contaminants exceeding environmental guidelines indicate a chemical hazard.
E5	Sediment contaminant concentrations (known or strongly suspected)	Measured concentrations of contaminants exceeding environmental guidelines indicate a chemical hazard.
E6	Surface water contaminant concentrations (known or strongly suspected) in relation to:	Measured concentrations of contaminants exceeding environmental guidelines indicate a potential chemical hazard.

No	Characteristic	Reason for considering
	• offsite migration in surface water • containment of surface water on-site • flood lines • contaminated surface water from the site entering an aquatic habitat	Surface water is considered contaminated for site-classification purposes if a contaminant in the surface water exceeds the RWQO for that catchment as these will have taken into account the various water users. However, this does not implicate every user upstream, and an assessment would need to be done. Containment measures such as those following would help to limit the contaminants leaving a site: • Fully contained: berms and dykes or contaminated soils are capped. • Partially contained: water movement offsite is delayed (i.e. in a sediment pond). • Not contained: no barriers between the site and nearby surface water. Flood lines: the site is not within the 100 year flood line or is > 100 m from a water resource.
E7	Groundwater contaminant concentrations (known or strongly suspected) in relation to: • offsite migration in groundwater • distance from a groundwater resource	Measured concentrations of contaminants exceeding guidelines (such as SANS 241) indicate a potential chemical hazard. Highly mobile contaminants will be washed out of soils and into groundwater more readily than chemicals with low mobility.
E8	Liquid state contaminants	For chemicals in the pure liquid state, the pure liquid state is generally the highest possible concentration at which an organic contaminant can be found. In the liquid state, contaminants have a greater potential to migrate (compared to the solid state) and thus may increase the size of the contaminated area. Chemicals that can be in a pure liquid state include PCB-containing oils, petroleum products and pesticide formulations.
E9	Number of contaminant classes at the site	Different contaminant classes generally have different modes of toxicity. Simultaneous exposure to more than one contaminant class may pose additional hazards to human or animal health or the environment.
E10	Size of the contaminated area or estimated quantity of all contaminants at the site	The larger the contaminated area or volume of contaminants on site, the higher the potential for contamination.
E11	Meteorological conditions	Contaminants could migrate offsite with soils (i.e. via dust dispersion) and be deposited hundreds of kilometres away.
E12	Type and depth of contaminated soils	The type and depth of contaminated soils can affect the migration of the contaminants in soils.
E13	Exposure of animals or plants to chemical contaminants	Invertebrates, for example, can include ants, earthworms, and centipedes. If contaminated soils are located within the top 1.5 m, it is assumed that plants and soil invertebrates may be exposed. Exposure to soils deeper than 1.5 m is possible, but less likely. Plants and soil invertebrates are generally exposed to a small

No	Characteristic	Reason for considering
		area of soil so they can be a sensitive indicator of potential environmental effects. In addition, plants and soil invertebrates can be important dietary components to animals. Consequently, they can contribute to the bioaccumulation of chemicals in animals and ultimately humans.
E14	Distance to sensitive areas such as a nature reserve or wetland	Sensitive areas such as nature reserves or wetlands located in the immediate area of the site will be more likely to be exposed to chemical contamination.
E15	Animals on site that may be ingesting contaminants or contaminated food	Ingested contaminated material can include food or soil. Most animals will ingest some soil while eating plant matter or soil invertebrates.
E16	Rare or protected species	Rare or protected species on the site or within close proximity to the site are likely to be affected by site contamination.

Similarly the following characteristics (Table 2) could be used to assess the likelihood of human-health impacts in a catchment.

Table 2: Characteristics that could be used to predict the likelihood of human-health impacts due to EDC contamination

	Characteristic	Reason for considering the characteristic
H1	The number of people potentially exposed to contaminants from the site or the number of people within a 1 km radius of the site	The greater the population potentially exposed to contaminants from the site, the greater the risk.
H2	Documented or strongly suspected impacts to human health from contaminants at the site	Impacts to human health are defined here as two or more people exhibiting adverse effects from what appears to be, or has been confirmed to be contaminant-related exposure.
H3	Sensitive land use such as a school, agriculture, hospital, church or residential area located within 1 km of the site	People living within 1 km of a contaminated site are more likely to be exposed to contaminants from that site than those people living further away.
H4	Accessibility of contaminated soils to humans	Contaminated soils may be accessible to humans if the area is not fenced or walled, or if soils are not covered in some way. Furthermore, geophagia (the eating of soil) is practised by some people.
H5	Direct exposure pathways to humans: • dermal • ingestion • inhalation	***Dermal:*** Exposure via the skin is generally believed to be a minor exposure route. However, for some organic contaminants, skin exposure is an important component of overall exposure. Dermal exposure can occur while swimming in contaminated water, bathing in contaminated surface water/groundwater, digging in contaminated dirt and during chemical handling. ***Ingestion:*** Contaminants can be ingested through drinking water, food

	Characteristic	Reason for considering the characteristic
		items and by accidental ingestion of contaminated soils. ***Inhalation:*** Inhalation can be via both particulates (dust) and gas (vapours). Dust - Soils are more likely to generate dust if they consist primarily of fine material (i.e., having a median grain size of 75 µm, as defined by the CCME (2006)). Vapours can be a problem where buildings have been built on former industrial sites or where volatile contaminants have migrated below buildings, resulting in the potential for vapours entering indoor air. The closer a person is to a source of volatile chemicals in soil, the greater the potential of exposure. In addition, coarser-grained soil will convey vapour much more efficiently in the soil than finer grained material such as clays and silts.
H6	The nearest drinking-water source	The closer a source of drinking water to a contaminated site, the greater the probability that the drinking water can become contaminated; a drinking-water supply can be a groundwater well or surface-water reservoir.
H7	Reliance on food items gathered within a 1 km radius of the contaminated site	Examples of animals providing local meats could include both wild animals such as snakes, lizards, snails, frogs and fish; or farmed animals such as chickens, pigs and fish. Some chemical contaminants accumulate in food, especially in fish and meats. Food products collected near a contaminated site have a greater probability of having some level of contamination and when consumed some of the contaminants are taken up.
H8	Unusual/unacceptable food tastes within 5 km of the site	Difference in taste is usually most apparent in fish or meat products.

Assessment of these characteristics will help to gain a good understanding of the various sites within the catchment and the identification of potential hazards/hazardous events.

An example of pre-screening for potential hazard identification is set out in Table 3.

Table 3: Example of screening as the second step in EDC risk assessment

Land use/ community type	General description of water-related activity	Potential hazard	Potential hazardous event	Take forward for further assessment?
Urban: activated sludge sewage-treatment works	Accepts industrial effluent	Industrial effluent containing EDCs	Acceptance of industrial effluent without first requiring treatment to remove EDCs	Yes
	Discharges treated effluent to river	Effluent containing EDCs	Discharge of effluent containing unacceptable level of EDCs due to inefficient removal	Yes
	Stabilises sludge on	Sludge containing	Disposal of sludge	Yes

Land use/ community type	General description of water-related activity	Potential hazard	Potential hazardous event	Take forward for further assessment?
	drying beds and then disposes to crop farmers	EDCs	containing unacceptable levels of EDCs to agricultural land	
Densely populated settlements	Standpipes without drains allowing greywater to collect in pools and ultimately flow down to the river in erosion channels	Greywater with potential EDCs	Flow of greywater to river	Yes
	Chemical toilets	Faecal contamination	Spillages and runoff during a storm event or with the greywater	Yes
Water-treatment works	Abstraction of raw water from river downstream of industrial zone	Raw water contaminated with EDCs	Inadequate removal of EDCs and distribution to consumers	Yes
Metal-plating industries	Discharges untreated industrial effluent to sewer	Effluent containing metal EDCs	Discharge of industrial effluent containing high concentrations of EDCs to sewer	Yes
	Stormwater from the site is channelled to the municipal stormwater channel which ultimately discharges to the river	EDC contaminated stormwater	Inadequate separation of clean and dirty stormwater on site allowing dirty stormwater into the municipal sewer	Yes
Crop farming (maize production)	Abstraction of raw water by farmers downstream of urban area for irrigation of maize crops	Raw water contains unacceptable levels of EDCs	Irrigation of crops with raw water containing unacceptable levels of EDCs	Yes
	Farmers plough sludge from sewage works into soil as fertiliser	Sewage sludge contains EDCs	Farmers plough sewage sludge containing EDCs into soil	Yes
	Farmers spray with pesticides during October/November	Pesticides	Stormwater containing pesticide residues reaches the river; pesticide spray reaches the water resource	Yes

Considering the examples given in Table 3, Figure 6 graphically illustrates the potential EDC pathways related either directly or indirectly to water, showing just how widespread EDCs are.

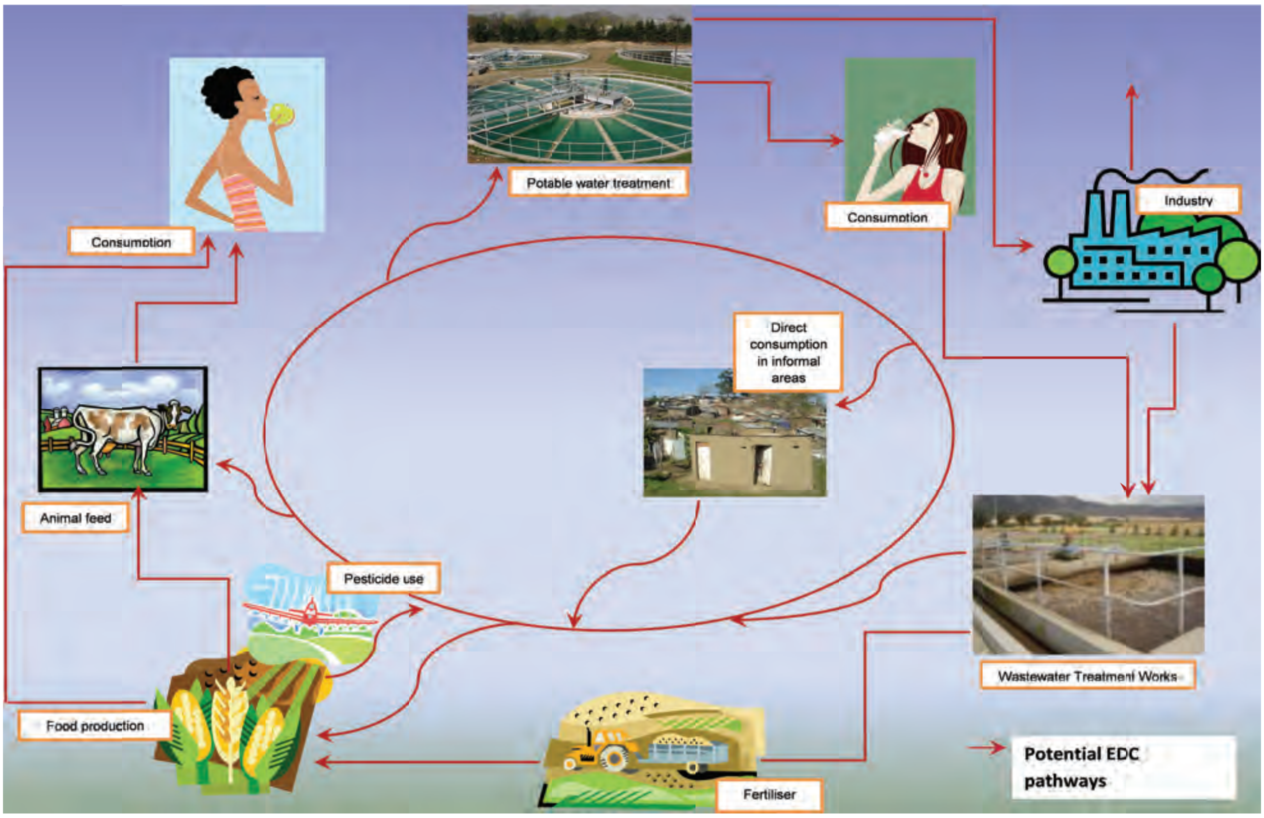


Figure 6: Illustration of potential EDC pathways related to catchment activities

Step 3: Risk mitigation

After the screening exercise the next step allows for the consideration of mitigation that is in place or could be put in place to reduce the risk associated with the identified hazard. The examples shown in Table 8 and Figure 4 are all linked either directly or indirectly to the EDCs emanating from the metal-plating industry, pesticides, and hormone-related EDCs that reach the sewage works.

Risk mitigation is supported by site-specific baseline investigations which allow for risk factors to be identified. This approach allows for risk mitigation, risk communication and the recognition of different exposure contributions for different systems (e.g. rural communities vs. commercial agriculture) to be incorporated into the management process.

In this respect the management mechanism proposed may remove the need to further assess the EDC risk; however, it is important to note that even though mitigation may be possible, the proposed mitigation may in fact be economically unsound. For example, removal of pesticide may mean a dramatically reduced crop yield.

It is important to note that even though the EDC concentrations are likely to be reduced by good management practices, uncertainty relating to EDC impacts remains high necessitating ongoing research. Notwithstanding this uncertainty, good management practices are likely to help considerably.

If the three main sources are considered in terms of potential mitigation, then the results seen in Table 3 change to those reflected in Table 4 and Figure 7.

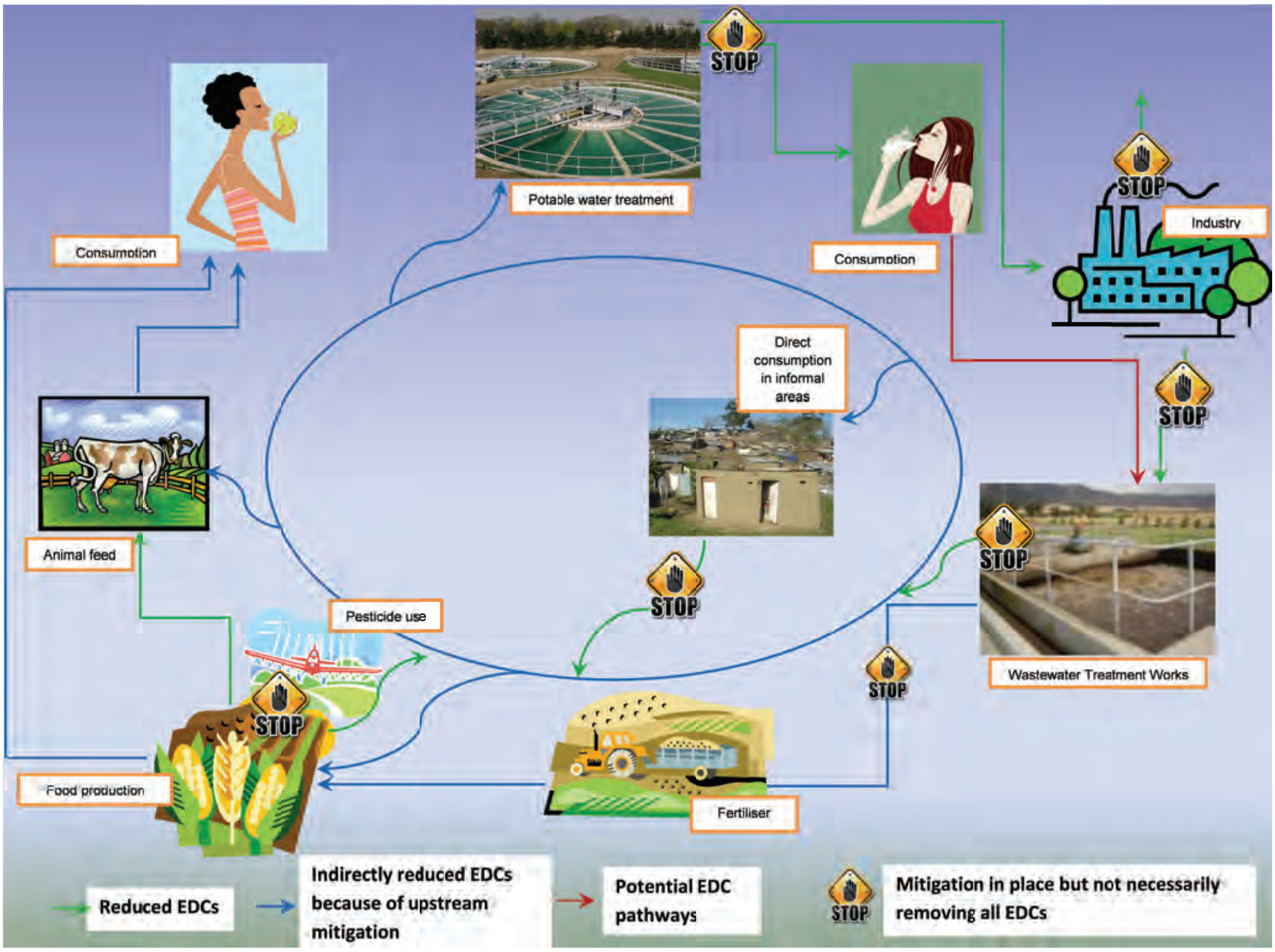


Figure 7: Illustration of change in EDC pathways as mitigation is put in place

Step 4: Risk prioritisation

Priorities for more detailed risk assessment should now be established. Table 4 shows that risk is assessed at two levels:

- maximum risk in the absence of preventive measures
- residual risk after consideration of existing or possible preventive measures

Assessing maximum risk is useful for identifying high-priority risks, determining where attention should be focused and preparing for emergencies. Residual risk provides an indication of the need for additional preventive measures. In the example given in Table 4, essentially only one area remains a priority where pesticide spraying cannot be stopped.

Table 4: Risk screening example after assessing risk-mitigation potential

Land-use type	General description	Potential hazard	Hazardous event	Take forward?	Mitigation potential	Take forward?
Urban: activated sludge sewage-treatment works	Accepts industrial effluent	Industrial effluent containing EDCs	Acceptance of industrial effluent (cadmium is a major contaminant and is a known EDC) without first requiring treatment to remove EDCs	Yes	Pretreatment that reduces/removes the cadmium prior to discharge will reduce the EDC concentration discharged to sewer.	No longer a priority, but monitoring should take place to audit the industry
	Discharges treated effluent to river	Effluent containing EDCs	Discharge of effluent containing unacceptable level of EDCs due to inefficient removal	Yes	There is an activated sludge process in which nitrification removes oestrone and estradiol (described briefly under *Best management practices* in **Chapter 2**). A programme to continuously assess process optimisation and effluent quality will reduce the probability of EDC contamination.	No longer a priority, but baseline needs to be established
	Sludge stabilised on drying beds and then disposed to crop farmers	Sludge containing EDCs	Disposal of sludge containing unacceptable levels of EDCs to agricultural land	Yes	Sludge disposed in accordance with the South African Sludge Guidelines* will reduce the EDC risk to crops.	No longer a priority, but audits need to take place to assess whether correct disposal is taking place; and if groundwater is used in the area then baseline of groundwater quality needs to be undertaken
Densely populated settlements	Standpipes without drains allowing	Greywater with potential EDCs	Flow of greywater to river	Yes	Flow of greywater removed because greywater drains installed and connected to	No longer a priority, but assessment of ongoing maintenance should

Land-use type	General description	Potential hazard	Hazardous event	Take forward?	Mitigation potential	Take forward?
	greywater to collect in pools and ultimately flow down to the river in erosion channels				sewer.	take place
	Chemical toilets	Faecal contamination	Spillages and runoff during a storm event or with greywater	Yes	Chemical toilet-emptying schedule increased so that spillages are reduced and flow of greywater removed because greywater drains installed and connected to sewer.	No longer a priority, but assessment of ongoing maintenance should take place
Water-treatment works	Abstraction of raw water from river downstream of industrial zone	Raw water contaminated with EDCs	Inadequate removal of EDCs and distribution to consumers	Yes	GAC used (described briefly under *Best management practices* in **Chapter 2**).	No longer a priority, but in order to be cost-effective, trends (e.g. seasonal) need to be established so that GAC is only used as necessary
Metal-plating industries	Discharges untreated industrial effluent to sewer	Effluent containing metal ECDs	Discharge of industrial effluent containing high concentrations of EDCs (cadmium is a major contaminant and is a known EDC) to sewer	Yes	Pretreatment plant installed and ongoing metal analysis showing drastically decreased concentrations.	No longer a priority, but ongoing assessment of optimal functioning of the treatment option must be done and metal concentrations monitored
	Stormwater from the site is channelled to the municipal stormwater channel which	EDC-contaminated stormwater	Inadequate separation of clean and dirty stormwater on site allowing dirty stormwater into the municipal stormwater	Yes	Clean and dirty stormwater areas are separated so that contaminated water no longer enters the municipal stormwater system.	No longer a priority, but ongoing maintenance of stormwater system must be done

Land-use type	General description	Potential hazard	Hazardous event	Take forward?	Mitigation potential	Take forward?
	ultimately discharges to the river		drain			
Stormwater containing pesticide residues reaches the river; pesticide spray reaches the water resource	Abstraction of raw water by farmers for irrigation of maize crops	Raw water containing unacceptable levels of EDCs	Irrigation of crops with raw water containing unacceptable levels of EDCs	Yes	No mitigation; however, upstream mitigation will reduce EDCs.	No longer a priority, but baseline needs to be established
	Farmers plough sewage sludge into lands	Sewage sludge containing EDCs	Farmers plough sewage sludge containing EDCs into soil	Yes	Sludge disposed in accordance with Sludge Guidelines* will reduce the EDC risk to crops.	No longer a priority, but audits need to take place to assess correct disposal is taking place; and if groundwater is used in the area then baseline of groundwater quality needs to be established
	Farmers spray with pesticides during October/November	Pesticides		Yes	Adequate buffers are maintained between the water resource and the fields thus reducing the amount of runoff that would reach the resource; however, spray may still reach the water resource.	Yes, but less of a priority. Assessment needs to take place

*Guidelines for the Utilisation and Disposal of Wastewater Sludge, Volume 2: Requirements for the Agricultural Use of Wastewater Sludge (Snyman and Herselman, 2006)

Colour coding	Links to other volumes
Priority areas for further research and ongoing risk assessment	Volume II: Sampling Guide Volume III: Bioassay Toolkit Volume IV: Monitoring and Assessment
Areas for further research, but not necessarily a priority if good practices are maintained and continuously assessed	Volume II: Sampling Guide Volume III: Bioassay Toolkit Volume IV: Monitoring and Assessment
Not a priority; however, further research would be relevant in order to establish a baseline	Volume II: Sampling Guide Volume III: Bioassay Toolkit Volume IV: Monitoring and Assessment

CHAPTER 4
RISK COMMUNICATION

Simply stated, risk communication is the process of informing people about potential hazards to their person, property, or community. People under stress typically want to know that you care before they care about what you know. Research has shown that people under stress typically have greater difficulty hearing, understanding and remembering information; risk communication is therefore central to informed decision-making (Covello and Allen, 1988).

Introduction

Public fear of EDCs can be likened to that of radioactivity and disease-causing bacteria and viruses: they are not readily detectable and introduce an additional risk of unknown magnitude that a population has to be protected against.

Even perceived threats to health and environment can be extremely precarious to the survival of the South African economy. It may easily fall prey to manipulated or spontaneous international actions to ban export products from South Africa due to high levels of specific pollutants (Burger, 2005).

Risk communication is a two-way exchange of information about threats, including health threats such as those related to the impacts of endocrine disrupting chemicals. The goals of risk communication are therefore to:

- enhance knowledge and understanding
- build trust and credibility
- encourage dialogue
- influence attitudes, decisions and behaviour

A central theorem of risk communication is that people's perceptions of the magnitude of risk are influenced by factors other than numerical data. This often results in two problems:

- Risks that are likely to harm people do not upset them so they fail to take appropriate precautions.
- Risks that are not likely to harm people nevertheless still upset them so they take unnecessary precautions.

Dr Peter Sandman, a risk communication expert pointed out that there is a low correlation between the technical seriousness of a risk, that is the risks that kill people, and its cultural seriousness, that is the risks that upset people; one never knows whether it upsets them or not, or how badly it upsets them (Sandman, 1987).

In the mid-1980s Sandman coined the formula *'Risk = Hazard + Outrage'* which reflected a growing body of research that indicated that people assess risks according to measures other than technical seriousness. Factors such as trust, control, voluntariness, dread and familiarity (widely known as outrage factors) (Table 5) are as important as mortality or morbidity (Sandman, 1987).

Table 5: Factors that influence people's perception of risks

Risk characteristics that prompt people to be *more accepting* and *less fearful* of the risk	Risk characteristics that prompt people to be *less accepting* and *more fearful* of the risk	Reasoning
Voluntary	Coerced/imposed	A voluntary risk is much more acceptable to people than a coerced risk, because it generates no outrage. Consider the difference between getting pushed down a mountain on slippery sticks and deciding to go skiing.
Under an individual's control	Controlled by others	Almost everybody feels safer driving than being a passenger. When prevention and mitigation are in the individual's hands, the risk (though not the hazard) is much lower than when they are in the hands of a government agency.
Fairly distributed	Unfairly distributed	People who must endure greater risks than their neighbours, without access to greater benefits, are naturally outraged – especially if the rationale for so burdening them looks more like politics than science. Greater outrage, of course, means greater risk.
Has clear benefits	Has little or no benefit	
Part of an open, transparent, and responsive risk-management process	Part of a secretive, unresponsive process	Does the organisation come across as trustworthy or dishonest, concerned or arrogant? Does it tell the community what's going on before the real decisions are made? Does it listen and respond to community concerns?
Generated by trustworthy, honest, and concerned individuals or organisations	Generated by untrustworthy, dishonest, or unconcerned individuals or organisations	
Natural	Manmade or industrial in origin	Most people perceive natural products as being good while man-made or industrial products are seen as being less beneficial or bad. Consider the positive slant given to breastfeeding as opposed to feeding synthetic formulae.
Statistical and diffused over time and space	Catastrophic	Hazard A kills 50 anonymous people a year across the country. Hazard B has one chance in 10 of wiping out its neighbourhood of 5 000 people sometime in the next decade. Risk assessment tells us the two have the same expected annual mortality: 50. 'Outrage assessment' tells us that A is probably acceptable and B is certainly not.
Affects adults	Affects children	In most societies children are perceived as being more vulnerable than adults to 'risky' activities.

Risk characteristics that prompt people to be *more accepting* and *less fearful* of the risk	Risk characteristics that prompt people to be *less accepting* and *more fearful* of the risk	Reasoning
Familiar/understood	Unfamiliar/exotic/dreaded	Exotic, high-tech facilities provoke more outrage than familiar risks (such as one's own home, car, food in the home). Similarly, certain illnesses are more dreaded than others; compare AIDS and cancer with, say, emphysema. The long latency of most cancers and the undetectability of most carcinogens add to the dread.
Moral	Immoral	Society has decided over the past two decades that pollution isn't just harmful – it's evil (EPA, 1987). But talking about cost-risk trade-offs sounds very callous when the risk is morally relevant. Imagine a police chief insisting that an occasional child-molester is an 'acceptable risk'.
Unremarkable	Memorable	A memorable accident makes the risk easier to imagine, and thus more 'risky'. A strong symbol, such as large oil drums, can do the same thing.

(Adapted from Covello et al., 1988 and Sandman, 1987)

As described by Sandman (1987) these 'outrage factors' are not distortions in the public's perception of risk; rather, they are fundamental parts of what is meant by risk. They explain why people worry more about well-publicised contaminated sites than geological radioactivity; and more about industrial emissions than aflatoxin in peanut butter.

There is inconsistency here in that many risk experts resist the pressure to consider outrage in making risk-management decisions, insisting that 'the data' alone, and not the 'irrational' public, should determine policy. However, experience and data generated over the past few decades has indicated that voluntariness, control, fairness, and the other aspects tabled above are important components of society's definition of risk. When a risk manager continues to ignore these factors – and continues to be surprised by the public's response of outrage – it is worth asking just whose behaviour is irrational (Sandman, 1987).

The solution is contained in reframing of the problem: since the public responds more to outrage than to hazard, risk managers must work to make serious hazards more outrageous and modest hazards less outrageous. For example, the campaign against smoking in public places was a successful effort where public concern was increased regarding the serious hazard of smoking by feeding the outrage.

Similarly, to decrease public concern about modest hazards, risk managers must work to diminish the outrage.

When people are treated with fairness, honesty and respect for their right to make their own decisions, they are a lot less likely to overestimate small hazards. At that point risk communication can help explain the hazard. But when people are not treated with fairness, honesty and respect for their right to make their own decisions, there is little that risk communication can do to keep the public from making trouble, regardless of the extent of the hazard.

Communication mechanisms

As discussed above, many of the obstacles to effective risk communication derive from the complexity, incompleteness and uncertainty of data. In addressing uncertainty, the following guidelines are useful:

- Acknowledge rather than hide uncertainty.
- Explain that risks are often hard to assess and estimate.
- Explain how the risk estimates were obtained and by whom.
- Announce problems and share risk information promptly, with appropriate reservations about uncertainty.
- Tell people that what you believe is either:
    - certain
    - nearly certain
    - not known
    - may never be known
    - likely
    - unlikely
    - is highly improbable
- Tell them what can be done to reduce the uncertainty.
- Tell people that what you believe now may turn out to be wrong later.

In this respect some fundamental rules for effective risk communication are described (Covello et al., 1988):

- **Accept and involve** the receiver of risk information as a partner as people have the right to participate in decisions that affect their lives.
- **Plan and adapt** risk-communication strategies as diverse goals, stakeholders, and communication channels require different risk-communication strategies.
- **Listen** to your stakeholders: people are usually more concerned about psychological factors, such as trust, credibility, control, voluntariness, dread, familiarity, uncertainty, ethics, responsiveness, fairness, caring and compassion, than about the technical details of a risk. To identify real concerns, a risk communicator must be willing to listen carefully to the stakeholders and understand the stakeholders.
- **Be honest and open** as trust and credibility are among the most valuable assets of a risk communicator.
- **Coordinate and collaborate** with other credible sources as communication about risks is enhanced when accompanied by referrals to credible, neutral sources of information. Few things hurt credibility more than conflicts and disagreements among information sources.
- **Plan for media influence** as the media play a major role in disseminating risk information. It is critical to know what messages the media deliver and how to deliver risk messages effectively through the media.
- **Speak clearly and with compassion** as technical language and slang are major barriers to effective risk communication. Abstract and unfeeling language often offends people. Acknowledging emotions, such as fear, anger, and helplessness are typically far more effective.

Risk-communication tools

Risk-communication tools are written, verbal, or visual statements containing information about risk. They should place a particular risk into context, add comparisons to other risks where appropriate, include advice about risk-reduction behaviour, and encourage a dialogue between the sender and receiver of the message. As described above, the best risk communication occurs where the stakeholders are informed, the process is fair, and the stakeholders are free and able to solve whatever communication difficulties arise.

Ideally, risk communication is a two-way conversation in which a group or organisation informs, and is informed by, affected community members.

It is of utmost importance that those drawing up risk messages should remember that a programme that addresses one source of conflict may fail to address another. Messages addressed to resolve disparities in one community might miss the mark in another because the issue may involve different values, from one individual or community to another, or there may be mistrust of certain experts.

In any form of communication, it is important to note the content of the message. The following points are important to remember when communicating a message:

- Know the stakeholders (specialists; non-specialists; young; elderly; and housewives).
- Determine what the stakeholders know.
- Get an understanding of what the stakeholders can be expected to understand.
- Ascertain what action or response is wanted from the stakeholders.
- Simplify complex information but make sure that the message content includes what you need to say to the particular stakeholders so that in this way you target the person(s) you are trying to influence.
- Know how (in what format) you want to pass the message on.

Developing a communication and implementation plan

Some basic questions to ask are:

- Who do you want to reach?
- What information do you want to distribute or communicate?
- What are the most effective mechanisms to reach your stakeholders?

Developing a communication and implementation plan will help to ensure that all the important elements have been covered before starting out. The plan itself provides a blueprint for action and does not have to be lengthy or complex.

The plan will be most effective when a variety of people are involved in its development. These may include:

- A communications specialist or someone who has experience in developing and implementing a communications plan.
- Technical experts in the subject matter (both scientists and policy experts, if necessary).
- Someone who represents the stakeholders (i.e. the people or groups you want to reach).

- Key individuals who will be involved in implementing the plan.

In developing the plan, consider whether there are any other organisations to partner with. For example, in South Africa, local and national government both have an important part to play in the protection and use of water resources and should ultimately work hand in hand when developing and implementing related policy and programmes. Other potential partners might include local businesses, environmental organisations, schools and associations. Partnerships can be valuable mechanisms for leveraging resources while enhancing the quality, credibility, and success of communication and implementation efforts.

Developing a communication and implementation plan is a creative and iterative process that will involve a number of interrelated steps that can be revisited and refined until an integrated, comprehensive, and achievable plan is realised.

Define the goals

Defining communication and implementation goals is the initial step in developing any plan. The goals should be clear, simple, action-oriented statements about what you hope to accomplish. Once the goals have been established, every other element of the plan should relate to those goals. An example of how this can be done is the use of a message map. An example of how this can be done is set out in Table 7.

Identify the stakeholders

The next step in developing the communication and implementation plan is to clearly identify the stakeholders. It may be necessary to refine and add to the goals once the stakeholders have been defined.

Stakeholders for such programmes may include:

- local communities
- local government
- provincial and national government
- researchers, educators and students
- industries
- special interest groups such as non-governmental and environmental organisations

It is important to note that some stakeholders may serve as conduits for dissemination of information to other stakeholders.

Profile the stakeholders

Once the stakeholders have been identified, the next step is to develop a profile of their situations, interests and concerns as well as their cultural or linguistic backgrounds. The programme will be most effective if the type, content and distribution of products are specifically tailored to the characteristics of the stakeholders. Developing a profile will help with the identification of the most effective ways of reaching the stakeholders. For each stakeholder group, consider the following questions:

- What is their current level of knowledge regarding the risk?
- What do you want them to know about the risk?

- What actions would you like them to take regarding the risk?
- What information is likely to be of greatest interest to the stakeholders?
- What new information will the stakeholders almost certainly want to know once they develop more awareness of the risk?
- How much time are they likely to give to receiving and assimilating the information?
- How (in what format) does this group generally receive information?
- In what professional, recreational and domestic activities does this group typically engage that might provide avenues for distributing the communication and implementation plan?
- Are there any organisations or centres that represent or serve the stakeholders and may be routes for disseminating the communication and implementation plan?

Message content: What do you want to communicate?

Now that the stakeholders have been identified and profiled the contents that must be communicated must be planned, in particular the key points, or messages, that must be communicated. These messages are the 'bottom line' information that the stakeholders need to take away, even if they forget the detail.

A message is usually phrased as a brief (often one-sentence) statement, for example:

- vector mosquitoes cause disease and death
- DDT is one of the few affordable and effective tools against malarial vector mosquitoes
- DDT has been detected in aquatic systems
- DDT is oestrogenic, acting on the endocrine system

A communication and implementation programme will often have numerous related messages such as those bulleted above. Consider what messages you want to send to each stakeholder group. Slightly different messages may be needed for the various stakeholder groups.

Message medium

Following on the development of the key messages, the next step will be to consider the types of medium ('products') that will be most effective for reaching each stakeholder group. There are many different types of media such as:

- print
- audiovisual
- electronic
- events
- even novelty items (such as soaps for a hand-washing programme)

A communications professional would be able to provide valuable guidance when choosing the most appropriate media to meet the goals within resource and time constraints; however, some pertinent questions to ask include:

- How much information does your stakeholder group actually need?
- How much does your stakeholder group need to know now? A simple, effective, straightforward product is generally the most effective.
- How easy and cost-effective will the product be to distribute or, in the case of an event, organize?
- How many people is this product likely to reach? For an event, how many people are likely to attend?
- What time frame is needed to develop and distribute the product?
- How much will it cost to develop the product? Do you have access to the talent and resources needed for development?
- What other related products are already available? Can you build on existing products?
- When will the material be out of date?
- Would it be effective to have distinct phases of products over time? For example, an initial phase of products designed to raise awareness, followed by later phases of products to increase understanding.
- How newsworthy is the information? Information with inherent news value is more likely to be rapidly and widely disseminated by the media.

Effective distribution

Effective distribution is essential to the success of any communication and implementation plan. There are many avenues for distribution. Some examples are:

- mailing list
- partner mailing lists upon request
- phone/fax/e-mail
- journals or newsletters of partner organisations
- internet
- meetings, events, or locations (e.g. libraries and schools)
- television/radio
- print media

It is important to consider how each product will be distributed and to determine who will be responsible for distribution. Some points to consider in selecting distribution channels include:

- How do the stakeholders typically receive information?
- What distribution mechanisms have been used in the past for this stakeholder group and were these mechanisms effective?
- Can you identify any partner organisations that might be willing to assist in the distribution?
- Can the media play a role in distribution?

- Will the mechanism you are considering actually reach the intended stakeholders? For example, the internet can be an effective distribution mechanism, but some groups might have limited access to it.
- How many people is the product likely to reach through the distribution mechanism you are considering?
- Are sufficient resources available to fund and implement distribution via the mechanisms of interest?

Follow-up mechanisms

Successful communication should result in requests for more information or expressing concern about issues that have been addressed. It is therefore necessary to consider whether and how this interest will be handled and to indicate on the product where people can go to for further information (for example, provide a contact name, number, or address, or establish a hotline).

Schedule for implementation

Once the goals, stakeholders, messages, products, and distribution channels have been identified and agreed upon, an implementation schedule will need to be drawn up. For each product, consider how much time will be needed for development and distribution. Be sure to factor in sufficient time for product review. Wherever possible, build in time for testing and evaluation by members or representatives of the stakeholders in focus groups or individual sessions so that you can get feedback on whether you have effectively targeted the material for the stakeholder groups.

Resources

Environmental topics are often technical in nature and scientific terminology is generally used. Nevertheless, technical information can be conveyed in simple, clear terms to those in the general public not familiar with water quality or other environmental fields. The following principles should be used when conveying technical information:

- Avoid using scientific terminology; rather translate technical terms into everyday language the public can easily understand.
- Use active voice.
- Write short punchy sentences.
- Use headings and other formatting techniques to provide a clear and organised structure.

When developing communication materials for the various stakeholder groups, remember to adapt the information to consider what the stakeholders are already likely to know, what else you want them to know, and what they are likely to understand. The most effective approach is to provide information that is valuable and interesting to the stakeholders.

Also, when developing communication products, be sure to consider any special needs of the stakeholders. For example, does the stakeholder group have a large number of people who speak little or no English? If so, prepare communication materials in the relevant language.

Figure 8 summarises the communication steps.

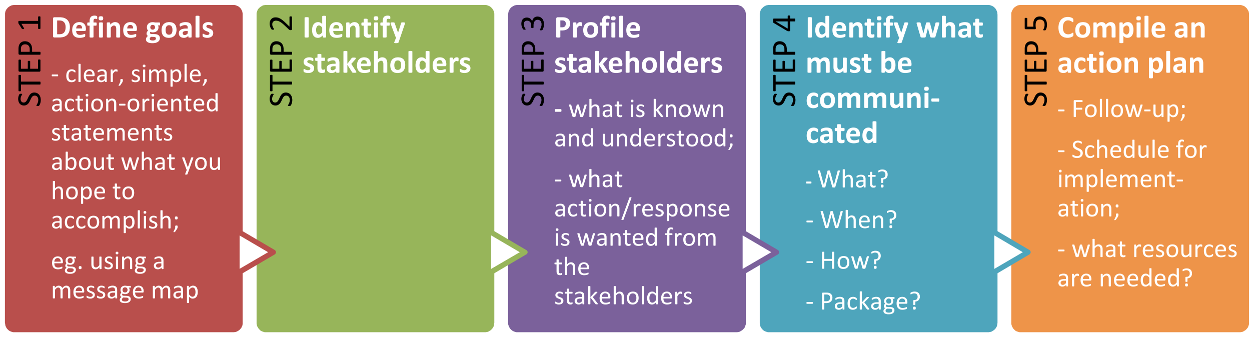


Figure 8: Diagrammatic summary of communication mechanism steps

Community boundaries

It is important to know the boundaries when dealing with risk (Table 6). These boundaries may be the natural, physical, administrative, social and economic characteristics that separate one community from another.

Table 6: Examples of community boundaries

Boundary type	Notes/examples
Natural	Geological features (e.g. watershed, mountain range) and landscape features (e.g. estuary, river, plains, foothills)
Physical	Features created by humans (e.g. major transportation corridors and bridges); characterised by location or use (e.g. rural, urban)
Administrative	Features created by government entities for political jurisdiction and for providing public services (e.g. local municipality; district municipality)
Social	Ethnic/cultural complexion of a particular place and organised social relationships around a place (e.g. civic associations)
Economic	Economic (e.g. blue- and white-collar workers)

These boundaries coexist at different scales; therefore, various risks can overlap between the boundaries. It is important to know about community boundaries in relation to risk, understanding where various risks lie and the perceptions of the risk.

Message map

One of the most effective tools for preparing clear and effective risk-communication messages is the ‘message map’. A message map contains detailed, hierarchically organised information designed to respond to anticipated questions or concerns. It is a visual aid that provides, at a glance, the messages to be delivered. Message maps allow risk communicators to develop messages in advance and can then be tested with the relevant stakeholders. An example is given in Table 7. In this example the concern that bis(4-chlorophenyl)-1,1,2-trichloroethane (DDT) is used in the control of malarial vector mosquitoes in certain areas of South Africa when it is banned in other countries, is considered.

Key messages about the question or concern must then be drawn up. Relevant facts/evidence that would support these key messages must then be compiled in a manner that would be understandable to the stakeholders. In other words, the complexity of the supporting facts/evidence may be different for different stakeholders. A simplified diagrammatic representation is shown in Figure 9.

Table 7: Example of a pre-event risk-communication message map when significant data are available

Stakeholders: Public and media

Question/concern: DDT, a known EDC is used in the control of malarial vector mosquitoes in certain areas of South Africa when it is banned in other countries. Why is this?

Key Message 1	**Key Message 2**	**Key Message 3**	**Key message 4**
Vector mosquitoes cause disease and death (WHO, *World Malaria Report 2010*)	DDT is one of the few affordable and effective tools against malarial vector mosquitoes (WHO, *World Malaria Report 2010*)	DDT has been detected in aquatic systems	DDT is oestrogenic, acting on the endocrine system
Supporting/related fact 1-1	**Supporting/related fact 2-1**	**Supporting/related fact 3-1**	**Supporting/related fact 4-1**
Malaria is a disease which can be transmitted to people of all ages. It is caused by parasites of the species *Plasmodium* that are spread from person to person through the bites of infected mosquitoes. If not treated promptly with effective medicines, malaria can often be fatal.	DDT is the only World Health Organization (WHO)-recommended chemical that provides all three levels of protection if the disease-carrying mosquito is not resistant.	DDT has been detected in aquatic systems in areas of South Africa (Limpopo, KwaZulu-Natal, Western Cape, Free State and Gauteng) (Viljoen, 2011).	DDT acts in a number of ways to disrupt endocrine function by binding with the oestrogen receptor, including oestrogen mimicry and antagonism, altering the pattern of synthesis or metabolism of hormones, and modifying hormone receptor levels (Soto et al., 1994; Lascombe et al., 2000; Kupfer et al., 1980)
Supporting/related fact 1-2	**Supporting/related fact 2-2**	**Supporting/related fact 3-2**	**Supporting/related fact 4-2**
One in five (20%) of all childhood deaths in Africa are due to malaria. It is estimated that an African child has on average between 1.6 and 5.4 episodes of malaria fever each year. Every 30 seconds a child dies from malaria in Africa.	A toxic chemical like dieldrin kills almost all of the mosquitoes that land on it, but also increases the chance for rapid build-up of resistance (Dr Donald Roberts, study author and Professor of Tropical Disease at the US Uniformed Services University of the Health Sciences).	DDT is highly lipophilic, nearly insoluble in water, and is very persistent with a half-life of 3 to 20 years depending on matrix and conditions (Viljoen, 2011).	Considering alternatives, the use of the pyrethroids has been limited because of their extremely high cost and the need for greater frequency of application when compared to DDT in the hot, humid conditions of the endemic malarial areas which are also in many cases isolated and difficult to access.
Supporting/related fact 1-3	**Supporting/related fact 2-3**	**Supporting/related fact 3-3**	**A balance needs to be achieved between the positive points and**
Worldwide about 3.3 billion people - half of the world's population - are at	Unlike dieldrin, DDT's spatial repellency acts like a chemical	The nature of field studies makes it very difficult to assign a specific	

Stakeholders: Public and media

Question/concern: DDT, a known EDC is used in the control of malarial vector mosquitoes in certain areas of South Africa when it is banned in other countries. Why is this?

risk of malaria. Every year, this leads to about 250 million malaria cases and nearly one million deaths. People living in the poorest countries are the most vulnerable (WHO, *World Malaria Report 2010*)	screen, keeping 59% of the mosquitoes out of the dwellings at the outset. By comparison, alpha-cypermethrin and dieldrin did not deter the study mosquitoes from entering huts.	cause or causes to observed effects. However, the disturbances observed have biological and toxicological plausibility (Viljoen, 2011).	**related facts in key messages 1 and 2 as opposed to the negatives points going out in key messages 3 and 4. Importantly, all aspects must be presented in a meaningful way to help the stakeholders make a decision.**
Supporting/related fact 1-4	**Supporting/related fact 2-4**	**Supporting/related fact 3-4**	
-	DDT has a comparatively long residual efficacy (≥ 6 months) as an insecticide for indoor residual spraying (IRS). DDT use in agriculture is banned under the Stockholm Convention, but countries can use DDT for IRS for as long as necessary and in the quantities needed, provided that the guidelines and recommendations of the WHO are met and until locally appropriate, cost-effective alternatives are available for a sustainable transition from DDT (WHO, *World Malaria Report 2010*).	Taken together with the results from human and other environmental studies done in this area, it is likely that at least some of the disturbances observed in this study can be associated with exposure to DDT in the environment. Although these effects are subtle, they are of concern and can affect biodiversity, environmental health, and possibly ecosystem function. Great care needs to be taken when using DDT and all possible precautions should be used to reduce and eventually eliminate its use (Viljoen, 2011).	

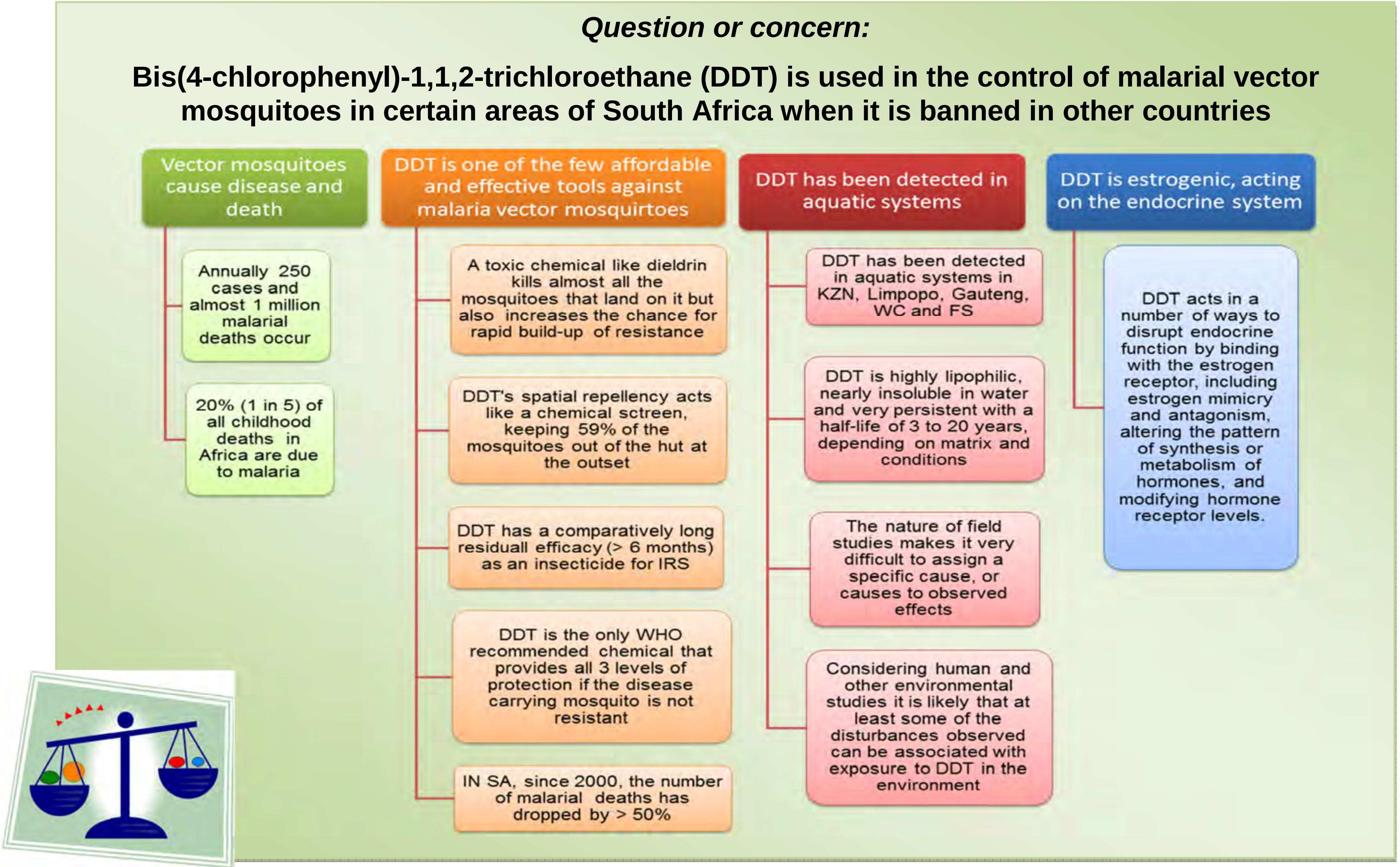


Figure 9: Diagrammatic representation of key messages and supporting facts

CHAPTER 5
RIETVLEI DAM CASE STUDY

In the case study that is presented here the methodology set out in the section on *Risk-assessment methodology* in **Chapter 3: Risk management**, has been used to show how an assessment can be done at catchment level.

The following section demonstrates how the abovementioned methodology could be applied.

Problem statement

Several studies during the period 2002 to 2007 (Barnhoorn et al., 2002; 2004; Muteveri, 2004; Vos, 2005; Bornman et al., 2007, *inter alia*) were undertaken on water, sediment, animals and fish in the Rietvlei Dam Nature Reserve. The results indicated oestrogenic disruption. The results of the water and sediment analyses from various studies have indicated that the Rietvlei Dam was polluted by both industrial and agrochemicals and that at the time of the studies, the water exhibited oestrogenic activity. There was therefore concern regarding human-health impacts from water being supplied by the Rietvlei WCW, which abstracts water from the Rietvlei Dam, to specific areas of Pretoria. However, to control the concentration of contaminants entering the water resources, upstream management options need to be put in place. In order to do this, potential contaminant sources need to be identified. The first step is therefore to characterise the catchment in terms of the land use and potential pollution sources.

Step 1: Catchment characterisation

The Rietvlei Dam is located in the Hennops River quaternary catchment (A21A) and is impacted by increasing urbanisation, industrial and agricultural activities. In other words, based on the results of the studies already undertaken, the dam is already seen as a 'hotspot'. Characterisation of the catchment in this respect will therefore be undertaken to assess the potential impacts on the Rietvlei Dam from upstream users.

There are two main tributaries that feed into the Rietvlei Dam:

- Rietvlei River with smaller perennial and non-perennial tributaries, namely:
  - Swartspruit
  - Elandsfontein Spring
- Hennops River

The main land-use types along the three rivers are urban formal, urban informal, agricultural holdings, industrial zone discharging to sewer, golf estate, sand quarry, brickworks, tunnel farming, chicken farm, sewage works, agricultural area, dam (Grootdam), Rietvlei Nature Reserve, and Rietvlei Water Care Works.

Step 2: Screening for potential EDC contamination: identification of potential hazards

In characterising the catchment, answers to questions relating to groundwater and surface-water migration potential; surface soil migration potential; and human and ecological exposure to EDCs; and in the context of IWRM, all other contaminants, will enable the manager to make a decision on the risks posed by various sites within the catchment. In this respect the characteristics listed in Table 1 and Table 2 of this report can be used to assess the likelihood of environmental damage or human-health impacts in a catchment.

Given that this guideline is considering EDCs in catchments and not only in drinking water, all potential hazards, sources and events that can lead to the presence of these hazards (what can happen and how) should be identified and documented for each component of the catchment and within the context of IWRM.

Considering the classes of EDCs prioritised in **Volume IV: Monitoring and Assessment** of the guideline series, the potential EDC classes can also be identified. Columns 1 and 2 of Table 8 describe the catchment activities and potential classes of EDCs that could be expected from the activities.

Step 3: Risk-mitigation potential

Now that the potential sources have been identified, the potential risk significance needs to be assessed to determine whether the risk is of high enough priority to warrant further monitoring. Essentially, under a normal water quality monitoring system, should a potential exist for contamination, then samples would be taken to quantify the risk in relation to some standard. However, with EDCs the sampling and analyses are considerably more complex and in many cases prohibitively expensive and the possible impacts can be significant and difficult to measure. Putting in place good management practices that could reduce or remove the contaminant from the environment is therefore a more appropriate option until further research is undertaken and the subject is better understood.

Step 4: Risk prioritisation

From the outcomes of Step 3, priorities for more detailed risk assessment and monitoring, as described in **Volume IV: Monitoring and Assessment**, can be established by assessing the risk at two levels:

- Maximum risk in the absence of preventive measures.
- Residual risk after consideration of existing or likely (will be put in place in the near future) preventive measures.

Assessing maximum risk is useful for identifying high-priority risks, determining where attention should be focused and preparing for emergencies whereas residual risk provides an indication of the need for additional preventive measures.

Column 5 of Table 8 sets out some examples of the outcome of implementing Steps 1 to 3.

Table 8: Examples of Steps 1 to 3 undertaken for the Rietvlei catchment

STEP 1		STEP 2		STEP 3
Water resource	**Upstream land-use type**	**Potential hazard: are there reasons to believe that EDCs may have an impact on the water source or associated water resource at the site – either directly or indirectly?**	**Potential EDC classes or specific contaminant, if known**	**Mitigation potential (options that are in place or could be put in place to remove or reduce EDCs reaching the environment)**
Rietvlei River	Urban formal	Runoff from roads and other urban surfaces such as plastic-coated roofing sheets	EDMs (especially lead); PCBs; plasticisers	▪ Reduce number of old cars on the road. ▪ Increased grassed areas and permeable pavements and parking areas. ▪ Removal of plastic-coated sheets from the market and replacement with alternatives. ▪ Implementation of by-laws in relation to oil storage and disposal; car washing, etc.
		Domestic waste discharge to sewer	Hormones; antibiotics	-
	Agricultural holdings (plots)	Runoff	PCBs; hormones; pesticides; herbicides; fertiliser; antibiotics	▪ Adequate buffer strips to absorb runoff. ▪ Awareness and implementation of by-laws regarding oil storage and disposal. ▪ Awareness and implementation of by-laws regarding number of animals (cattle and sheep) per property. ▪ Pesticides, herbicides and fertilisers added according to specifications and not in excess.
	Industrial zone	Runoff and contaminated stormwater	EDMs, PCBs	▪ Containment of contaminated stormwater so that it doesn't reach the water resource. ▪ Awareness creation and implementation of by-laws relating to stormwater management.
		Discharge of industrial effluents to sewer	EDMs	▪ Pretreatment of effluents. ▪ Implementation of by-laws to ensure that water-use licence conditions of sewage works are complied with.
	Sewage works	EDCs from hormones and antibiotics contaminate final	Hormones;	The Hartebeestfontein WWTW differs from the traditional activated sludge works in that it utilises a two-stage, two-culture activated sludge

STEP 1		STEP 2		STEP 3
Water resource	**Upstream land-use type**	**Potential hazard: are there reasons to believe that EDCs may have an impact on the water source or associated water resource at the site – either directly or indirectly?**	**Potential EDC classes or specific contaminant, if known**	**Mitigation potential (options that are in place or could be put in place to remove or reduce EDCs reaching the environment)**
		effluent	antibiotics	process. Each stage is a complete processing unit comprising aeration, clarification and sludge return. The primary stage is aimed principally at COD (chemical oxygen demand) removal and the secondary stage at nitrification. It is known that an activated sludge process in which nitrification occurs removes oestrone and estradiol (Section on domestic wastewater in **Chapter 3**). Should a programme to continuously assess process optimisation and effluent quality be put in place, the probability of EDC contamination will be reduced.
		EDCs from industry contaminate final effluent	EDMs	Promulgation and implementation of by-laws relating to disposal of EDMs to sewer; this may involve industries having to pre-treat to a certain concentration; or levying of industrial effluent charges that would allow the WWTWs to be upgraded.
		Runoff from sludge disposal area	EDMs; alkylphenols; and plasticisers	Adequate buffer strips in place to prevent runoff to water resources even if sludge is ploughed into lands for cultivation.
		Bioaccumulation in crops grown on sludge and then eaten by animals	EDMs; alkylphenols; and plasticisers	Bioaccumulation is of concern here and further research may be needed.
		Bio-accumulation of	PCBs; hormones;	

STEP 1		STEP 2		STEP 3
Water resource	**Upstream land-use type**	**Potential hazard: are there reasons to believe that EDCs may have an impact on the water source or associated water resource at the site – either directly or indirectly?**	**Potential EDC classes or specific contaminant, if known**	**Mitigation potential (options that are in place or could be put in place to remove or reduce EDCs reaching the environment)**
		contaminants in fish	pesticides; herbicides; fertiliser; antibiotics	
	Rietvlei Water Care Works	EDC-contaminated water reaching consumers	PCBs; hormones; pesticides; herbicides; fertiliser; antibiotics	Granular activated carbon (GAC) filtration is used by Tshwane Metro as a tertiary treatment process. The practical use of GAC had to be researched and adapted to South African circumstances. The GAC filtration system is the first application of open-bed gravity filters for potable water treatment in South Africa. The system includes a purpose-designed, simple GAC transfer facility to enable the reactivation of the GAC on a regular basis. Automation of the operation of the GAC filters was done and the system has been integrated into the existing plant control system.

If the above good management practices were to be implemented, a reduction in EDC contamination reaching the dam could be expected. Currently the Rietvlei WCWs uses granular activated carbon (GAC) in the process, at great expense, ensuring that the water supplied is of a quality that is fit for human consumption and will have limited human-health impacts over the longer term.

Communication

It is known that there is still a problem with the quality of the water in the dam, so how should it be communicated to the interested and affected parties without being alarmist. Risk communication is a two-way exchange of information about threats, including health threats such as those related to the impacts from endocrine disrupting chemicals present in the dam from which drinking water is abstracted. The communications team for the water service provider therefore need to enhance knowledge and understanding of:

- The upstream impacts and potential mitigation that could be put in place to reduce release to the environment.
- The technologies in place at the Rietvlei WCWs to counteract the existing problem.

In creating this awareness and understanding, trust and credibility will be built while encouraging dialogue. Once the stakeholders have a better understanding of the bigger picture and that all upstream users should be implementing good management practices, this will influence attitudes towards their own decisions and behaviour in relation to:

- Managing their own impacts on water.
- The pressure that they put on the upstream users to implement best practice.

Assessing the stakeholders

While catchment characterisation has taken place for the A21C catchment, the interested and affected stakeholders will extend downstream of this catchment in respect of consumers of the treated drinking water, as well as the users of the water resource.

Potential stakeholders in the area would be:

- Department of Water Affairs
- Tshwane Metropolitan Council
- Ekurhuleni Metropolitan Council
- ERWAT
- representatives of local residents:
  - smallholdings
  - urban formal
  - urban informal
- industries upstream of the dam
- industries discharging to the Hartebeestfontein WWTW
- agricultural land owners;
- tunnel farmers
- chicken farmers
- media

In order to better manage the meetings, these groups may need to be split to avoid conflict. This is important because while creating awareness of the concerns, the communication stream will also be informing the stakeholders that they too may be adding to the pollution load entering the dam. This could be done using a message map described in the section on *Risk communication* in **Chapter 4**. Table 9 sets out some options.

Table 9: Example message map for the Rietvlei catchment

CONCERN/QUESTION: Are there EDCs in the Rietvlei Dam and what impact will they have on my health if I drink the water supplied by the Rietvlei Water Care Works?		
Key Message 1	**Key Message 2**	**Key Message 3**
What are EDCs?	**EDCs are present in the Rietvlei Dam from where water is abstracted for treatment prior to distribution**	**Granular activated carbon has been proven to be the best available technology to remove EDCs**
Supporting/related fact 1-1	**Supporting/related fact 2-1**	**Supporting/related fact 3-1**
An endocrine disruptor is an exogenous substance or mixture that alters function(s) of the endocrine system and consequently causes adverse health effects in an intact organism, or its progeny, or (sub)populations (WHO, 2003).	Chemical and biological analyses indicated that residues of PCBs, octyl- and nonylphenol are present in water and sediment samples taken from the dam.	GAC treatment removes contaminants via the physical and chemical process of sorption. The contaminants accumulate within the pores and the greatest efficiency is attained when the pore size is only slightly larger than the material being adsorbed.
Supporting/related fact 1-2	**Supporting/related fact 2-2**	**Supporting/related fact 3-2**
General classes of chemicals of chemicals considered to be endocrine disrupting include: • some inorganic compounds • insecticides • herbicides • fumigants • fungicides • detergents • resins • plasticisers	Bio-accumulated lindane, DDT and metabolites and PCB153 have occurred in fat samples of eland living in the nature reserve and drinking from the dam.	Removal efficiencies for many organic contaminants are good to excellent. However, water quality parameters such as dissolved organic matter, pH and temperature can significantly affect the removal efficiency of GAC. It is important to note that for GAC treatment of drinking water it is necessary to reduce the total organic carbon (TOC) of the treated water through the preliminary steps of coagulation/filtration. Its removal efficiencies therefore change drastically once the bed nears exhaustion as contaminant breakthrough occurs.
Supporting/related fact 1-3	**Supporting/related fact 2-3**	**Supporting/related fact 3-3**
EDCs are therefore ubiquitous and emanate from many sources.	Sexual abnormalities were noticed in the sharptooth catfish and freshwater snail found in the dam; the striped mouse found in the nature reserve showed a relatively low sperm count; and calcifications were noted in the eland living in the nature reserve.	GAC is the best available technology for the removal of all or many EDCs. However, other technologies such as coagulation/filtration and lime softening, used in the multistep process of treating water to potable quality, enhance the performance of GAC.

Key Message 4	Key message 5	Key message 6
Rietvlei WCWs uses GAC	**There are various sources in the upstream catchment**	**If best management practice is put in place at the various sources (municipal, agricultural and industrial) EDC concentrations would decrease in the dam**
Supporting/related fact 4-1	**Supporting/related fact 5-1**	**Supporting/related fact 6-1**
Granular activated carbon (GAC) filtration is used by Tshwane Metro as a tertiary treatment process. The practical use of GAC had to be researched and adapted to South African circumstances.	Sources of EDCs emanate from: Agriculture; urban areas (formal and non-formal); WWTWs; and industrial areas.	Currently best management practice is not in place.
Supporting/related fact 4-2	**Supporting/related fact 5-2**	
The GAC filtration system is the first application of open-bed gravity filters for potable water treatment in South Africa. The system includes a purpose-designed, simple GAC transfer facility to enable the reactivation of the GAC on a regular basis. Automation of the operation of the GAC filters was done and the system has been integrated into the existing plant control system.	Table 8 shows the potential classes of EDCs emanating from the various sectors, such as: • urban formal: EDMs (especially lead); PCBs; plasticisers • agricultural holdings: PCBs; hormones; pesticides; herbicides; fertiliser; antibiotics • industrial zone: EDMs, PCBs • sewage works: antibiotics; hormones	

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