

**EXTENDED STRATEGIC PLAN FOR THE  
ENDOCRINE DISRUPTOR RESEARCH  
PROGRAMME OF THE WRC 2006-2010**

**Volume 3**

Report to the  
**Water Research Commission**

by

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## FOREWORD

Throughout the world there is growing concern about the effects that Endocrine Disrupting Compounds (EDCs) may have on humans as well as on wildlife. EDCs can be natural or man-made substances which interfere with the normal functioning of the endocrine system. These compounds include pesticides as well as a wide range of substances used or produced by industry. Since all EDCs eventually find their way into the environment and water resources, the Water Research Commission (WRC) took the initiative in South Africa to launch a coordinated EDC research programme involving researchers and other role players such as government departments, industry and water suppliers. The first strategic research programme for EDC research was formulated in 2000 and implemented during 2001-2005 by the WRC. This report is the third in the series, consisting of the following reports:

### **Volume 1**

WRC Programme on Endocrine Disrupting Compounds (EDCs) Volume 1. Strategic Research Plan for Endocrine Disrupters in South African Water Systems (WRC Report No. KV 143/05).

### **Volume 2**

WRC Programme on Endocrine Disrupting Compounds (EDCs) Volume 2. Implementation of a Research Programme for Investigating Endocrine Disrupting Contaminants in South African Water Systems (WRC Report No. 1402/1/08).

### **Volume 3**

WRC Programme on Endocrine Disrupting Compounds (EDCs) Volume 3. Extended Strategic Plan for the Endocrine Disruptor Research Programme of the WRC, 2006-2010 (WRC Report No. KV 228/09 – **this report**)

### **Volume 4**

WRC Programme on Endocrine Disrupting Compounds (EDCs) Volume 4. Implementation of an Extended Strategic Research Plan on Endocrine Disruptor Chemicals in Water Resources (Report in preparation).

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## EXECUTIVE SUMMARY

A research programme on Endocrine Disrupting Compounds (EDCs) was initiated by the Water Research Commission (WRC) in 2001. At this stage it was unknown whether any EDCs were present in South African water systems. The aims of the programme were to establish the current state-of-the-science in South Africa and to launch a coordinated programme incorporating the skills of different research organisations to determine the occurrence and source of EDC contamination in the country. This was a relative new field of research worldwide and the subject of groundbreaking research in South Africa. A strategic research plan was developed and implemented (Volume 1: WRC Report KV143/05).

It soon became clear that the current chemical analytical methods used to determine any of the EDCs previously measured as toxicants were not suitable for this research, since the detection limits of these methods were too high. Furthermore, the country did not have the capability to determine certain important EDCs such as hormones, dioxins and alkylphenols. Subsequently, chemical analytical methods were revised and, where necessary, new methods were developed and implemented (WRC Report 1402/1/08 – Volume 2 of this series). Over and above the chemical analysis of samples to determine EDCs, there was also a need to monitor samples for endocrine disruptive (ED) activity which required suitable biological/biochemical methodology. Methods were available internationally, but they had to be implemented and verified in South Africa. Bioassays for activity testing only determine the *total activity* of EDCs in a specific aquatic system and provide no information on the identity of the pollutant. Unfortunately no single test exists to determine the ED effect on all the specific hormone systems in a living organism and therefore a battery of tests would be needed to get a better understanding of the extent of ED activity. The existing methods are, however, essential tools to use for screening purposes. All EDCs present in unknown quantities in a specific system cannot be detected using a single chemical analytical procedure due to the diversity of these chemicals and their breakdown products. Ultimately, the cost of the analysis becomes exorbitant.

During the implementation of the EDC research programme, certain new issues were raised that also needed attention. These included knowledge concerning the fate and behaviour of chemicals in the environment and in waste water treatment works, the physiology of animals used as biomarkers and the effects of EDCs on endocrine systems other than the reproductive system (e.g. nervous system, immune system and thyroid function). A multidisciplinary understanding of the *total effect* of EDCs on living organisms is needed to develop a risk assessment model. Such a model may then be used to set guidelines for acceptable levels of these compounds in drinking water and the environment for sustainable ecosystems. Some of these issues were addressed and implemented during the execution of the second phase of the Strategic Research Programme (Volume 2, WRC Report 1402/1/08).

The programme also needed revision to include new trends in analysis and evaluation and incorporate and use new technologies. EDC activity was found at four selected sites during the first phase and certain EDCs were identified and their effects on humans and wildlife were observed. Since occurrence was confirmed, it now became necessary to be able to get a better understanding of the situation and to manage the pollution problem.

The aim of this report (Volume 3 of the series) was to evaluate, review and update the preceding strategic research programme (Volume 1: WRC Report KV 143/05) as well as the implementation of

the first phase and recommendations from the second phase (Volume 2: WRC Report 1402/1/08) to ensure that the EDC Research Programme addresses all the relevant factors and that a more comprehensive picture of the ED effects on humans and wildlife could be obtained. A new extended strategic research plan has been formulated to address the needs of all stakeholders.

The objectives of the new extended strategic research plan may be described as follows:

- The outcome of the programme should provide a sound scientific base (relevant and sufficient information) to be developed to manage the EDC contamination problem.
- At the same time it should make provision for the development of analytical tools that scientists can use to determine the levels and source of EDCs in water resources.

A needs and gaps analysis was conducted at two workshops attended by the role players. At these workshops knowledge gaps were identified and several project proposals were developed in conjunction with the main researchers in this field. For each individual project a time scale and budget were also proposed. These projects cover a wide range of research subjects: the study of the effects of EDCs on the thyroid function and immune system and analytical methods to measure these effects, the occurrence of veterinary drugs in water systems, the effect on humans living in a DDT spraying area and the development of a human risk assessment model for EDC exposure. The **needs** were summarised and prioritised as follows:

- The need for reliable and credible data on the occurrence and magnitude of EDC pollution.
- Information regarding the fate and behaviour of EDCs in the environment and in the human body.
- Models for risk assessment.
- Relevant and affordable analytical methods with quick turnover.
- Facilities for analytical procedures

As a result of combining the needs identified by stakeholders from various sectors with the overall gap in available knowledge, it is proposed to develop a comprehensive research programme to guide future research into the effects EDCs may have on both humans and animals. To achieve this goal, it is necessary to address the problem at two levels:

- **Fundamental research: providing a scientific base for data acquisition and policy development.**
- **Applied research: development of management tools**

The first three abovementioned needs can be classified as being *management tools*. The remaining two needs are tools for *scientific project execution*. Although EDCs are not a new problem, it is only during the past twelve years that scientists have become aware of the extent to which we are exposed to these chemicals. Water is only one of the exposure pathways, but water pollution is a very sensitive issue. The management of EDC pollution in our water resources has become of cardinal importance. Knowledge of the **magnitude** of the pollution and the **risk** it poses to humans, animals and the ecosystem is essential for the management of the problem. The country needs a clear policy to address the pollution of EDCs in our water systems. All future research should be aimed at providing the tools needed for the ultimate development of policies to manage EDC pollution in South African water systems. The research projects funded and managed by the WRC should develop

these tools that could be used in managing and in policy development for stakeholders to minimize pollution in water systems. The proposed research programme for **fundamental research** will eventually produce a risk assessment model capturing the effects that EDCs have on human and animal health which should provide a sound base for the development of such a policy.

An action plan is proposed for **applied research** to investigate the impact of agricultural and industrial chemicals with ED properties, as well as chemicals excreted by humans that may eventually reach the aquatic environment. This information is needed to determine the magnitude of EDC pollution.

For the implementation of the programme, it is necessary that the researchers should be given the best support available. It is therefore important that facilities should be provided to research and develop new and appropriate analytical techniques. It is recommended that this research should focus on the analysis and determination of both EDC activity and the chemical analysis of aquatic samples. The researchers could investigate and negotiate with other organisations such as the CSIR and SABS to provide these facilities. Universities should be encouraged to form self-supporting institutes at their facilities in order to provide an analytical service to researchers and to the public. This will also create an opportunity for career building for students. Capacity needs to be built, both organisational and human resource capacity. During the execution of the first part of this programme, several post-graduate students were trained and involved in the projects. They left the field, however, because they could not find jobs. It is therefore important to address this and to secure the capacity within this field of interest and in the country.

It is not within the framework of the WRC to establish a monitoring programme. The WRC should, however, support the initiative of DWAF in their effort to put such a programme in place. EDC research is expensive and alternative sources of funding should be found to supplement the funding of the research.

This report, the third in the series, provides an extended strategic research plan for the EDC research programme of the WRC for 2006-2010. It aims to meet and address the needs of all stakeholders and the country as a whole.



## TABLE OF CONTENTS

Foreword .....	iii
Acknowledgements.....	iv
Executive Summary .....	v
Table of Contents .....	ix
1. Background .....	1
1.1 Health implications of EDCs .....	3
1.2 Influence of EDC contamination on wildlife and ecosystems .....	4
1.3 Economic and industrial implications of EDC contamination .....	4
1.4 Conclusion and recommendations .....	4
2. Methodology .....	5
2.1 Needs and gaps analysis .....	5
3. A Framework for Future Research in the EDC Programme .....	12
3.1 Fundamental research (policy development) .....	13
3.2 Applied research .....	15
3.3 Selection of research projects to satisfy needs of stakeholders .....	19
3.4 Remedial action .....	19
3.5 Education and knowledge dissemination .....	19
3.6 Funding .....	19
3.7 Conclusions .....	20
3.8 Recommendations .....	20
4. Literature References .....	22

## LIST OF FIGURES

Figure 3.1	Framework for future research .....	13
Figure 3.2	Framework for applied research .....	16

## LIST OF TABLES

Table 3.2.5	Proposed time frame for EDC programme .....	18
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## 1. BACKGROUND

Since the latter half of the twentieth century, there has been growing concern about the adverse effects that a number of chemicals may have on human health and also on wildlife. These chemicals have the potential to alter the normal functioning of the endocrine system and are therefore referred to as Endocrine Disrupting Compounds (EDCs). Many compounds that are in daily use in industry, agriculture and in households have ED (endocrine disruptive) effects. These include the alkylphenols, polychlorinated biphenyls, dioxins and furans, and organochlorine compounds, which are used in different forms as plasticizers, lubricants, packaging material, fire retardants, pesticides and insecticides. Dichloro-diphenyl trichloro-ethane (DDT) and other organochlorine pesticides are well known for their ED effects.

In the early 1990s awareness grew of the need for large-scale research to improve our knowledge of EDCs and their presence and effects in the South African environment. A need existed for a coordinated research programme involving all researchers and other role players, including government departments, industry and water suppliers. In 1999, the Water Research Commission (WRC) took the initiative and launched the EDC Research Programme to coordinate and extend present capacity to undertake research in this field. The main objective of the programme was at first to investigate the occurrence and source of EDC pollution in South African water systems and then to determine to what extent the population and the environment are at risk by being exposed to these chemicals. Building on the knowledge of EDCs and their presence in the environment, decision-makers will be able to ensure that these chemicals are effectively controlled through legislation to reduce risk of exposure.

The study of EDCs and their effects on the environment requires a multidisciplinary approach, involving research in disciplines such as zoology, physiology, toxicology, bioassays and analytical chemistry, statistics and risk assessment. The programme focussed on a list of priority EDCs compiled in collaboration with stakeholders such as the Department of Water Affairs and Forestry (DWA) and the Global Water Research Coalition. The programme also focussed on building much needed capacity at the participating research facilities for ED activity testing and chemical analysis. Research institutions were encouraged to build human resource capacity, especially by training students from previously disadvantaged groups.

The first strategic research plan aimed to determine the occurrence of EDCs in South African water systems (WRC Report KV 143/1/05 as Volume 1 of the strategic research programme). Out of the initial research plan, the implementation (WRC Report 1402/1/08) of the plan followed, addressing the occurrence of EDCs, developing of analytical methods to determine the ED activity and confirmation by chemical analysis. Capacity building was a crucial component of the first phase.

Apart from this, the WRC has funded other research projects evaluating specific methods for ED activity testing and chemical analysis (WRC Reports 926 & 1253/1/05). As a follow up, the WRC also supported the implementation of Phase 1 (WRC Report 1402/1/08), as well as supporting two pilot studies where local, endemic vertebrate species in and around an urban nature reserve were evaluated as bio-indicators of EDC activity (WRC Report 1505/1/07) and where the presence of estrogenic activity during the various processing steps of drinking water treatment were evaluated (WRC Report 1532/1/08)

Despite the progress made through the EDC Research Programme to date, many uncertainties still remain. In lieu of these uncertainties, the WRC has formulated a strategic research plan to guide and coordinate research undertaken in this field. The strategic research reports that have already been published have identified specific knowledge gaps and made recommendations to address these:

- **WRC Programme on Endocrine Disrupting Compounds (EDCs) Volume 1: Strategic Research Plan for Endocrine Disruptors in South African Water Systems, (WRC Report KV 143/05)**

This report focussed on the state of EDC research in SA, evaluating the existing data, analytical techniques and laboratories for the determination of the identified group of pollutants. It also reported on the needs of various stakeholders and identified the relevant knowledge gaps. Recommendations deriving from the needs and gaps identified were:

- A national programme for monitoring of EDCs and toxicants to generate data which may be used by authorities to manage the pollution of SA water resources;
- The need for the establishment of an independent and accredited analytical facility for the determination of EDCs and toxicants;
- Suitable methods for the identification of EDCs and for the determination of EDC effects on humans and wildlife;
- A human health risk assessment model; and
- A training programme for scientists and students working in this field.

- **WRC Research Programme on Endocrine Disrupting Compounds (EDCs) Volume 2: Implementation of a Research Programme for Investigating Endocrine Disrupting Contaminants in South African Water Systems, (WRC Report 1402/1/08).**

This report provided an in-depth evaluation of laboratories and analytical techniques used for the determination of EDCs in water, sediment, biological tissue, food and dairy products. Results from an inter-laboratory study of the analysis of samples from four sites, were also presented. The following were listed as needs to address:

- Update of the list of priority EDCs used for reference purposes on an annual basis;
- Annual update of the list representing the capacity and capability of laboratories to do chemical analysis and bioassays;
- Development of bioassays to determine pollutants at ultra trace levels;
- Improvement of quality of analysis at laboratories, especially their ability to handle large numbers of samples;
- Establishment of a facility for the determination of dioxins and furans;
- Involvement of all water and government laboratories in future studies;
- Building of human resource capacity and career opportunities;
- Development of a relevant human risk assessment model;
- Establishment of an ongoing surveillance programme to ensure the safety of water resources; and
- Development of a management programme and the continuous sampling of water resources for risk assessment.

Following these recommendations and taking the results from current research (undertaken following the recommendations from Volumes 1 and 2) into consideration, it is now necessary to re-evaluate the programme and develop a strategic research plan for the next few years (2006-2010).

This will be done by addressing certain aspects of EDC pollution of water resources such as health implications, influence on wildlife and ecosystems, and the economic and industrial implications of EDC contamination.

## **1.1. Health Implications of EDCs**

The endocrine system comprises a number of complex physiological processes by which the body can respond to a range of internal and external signals and stresses. Hormones are the chemical messengers of the body that are secreted from the endocrine glands directly into the blood and are involved in regulating the growth, development and functions of the body.

A diverse range of chemicals discharged into the environment can mimic or antagonize the action of hormones. These EDCs may interact with the physiological systems of humans and wildlife, causing alterations in their development, growth and reproduction.

### **1.1.1 ED effects on the reproductive system**

Exposure to male embryos in the early stages of development has been linked to the increased incidence of male reproductive health disorders including hypospadias, undescended testes, intersex, subfertility and testicular cancer (Paulozzi 1999; Sharpe and Skakkebaek 1993; Toppari et al., 1996).

Female reproductive health and fertility, particularly conditions like endometriosis and adenomyosis of the breast and reproductive tract, cancer and possibly polycystic ovarian syndrome seem to be mediated by EDCs (Gerhard et al., 1992). Foetal exposure to EDCs was found to influence reproductive and general health.

### **1.1.2 ED effect on the nervous system and thyroid function**

The nervous system and thyroid function play an integrative role along with the endocrine and immune system in orchestrating important physiological functions in the body. The integrative functions are critical for normal development and cognitive functions and behaviour. A number of environmental chemicals (including potential EDCs) have been shown to cause neurotoxic effects (WHO, 2002). A variety of adverse health effects have been observed ranging from motor impairment and memory loss to subtle behavioural changes (Spencer and Schaumburg, 2000). Of particular concern are the potential effects of the exposure on the developing nervous system, because both the nature and adversity of the outcome may depend on the time window during which the chemical exposure occurs and result in irreversible neuro-behavioural changes later in life. EDCs are very likely the causal effect of disturbances in the cognitive and immunological development of children (Tilson, 1998).

### **1.1.3 ED effect on the immune system**

The major function of the immune system is defence against infectious agents and certain neoplastic cells. Various cell types and their soluble mediators execute this function of the immune system in a finely tuned manner. Toxic responses may occur when the immune

system acts as a passive agent of chemical insults, leading to altered immune function. Toxicity may also arise when the immune system responds to the antigenic specificity of the chemical as part of a specific immune response, that is, hypersensitivity or allergy. Chemically induced toxicity, in which the immune system is the target, can result in immunosuppression and potential disease susceptibility (WHO, 2002). This is of special concern in South Africa with the high rate of HIV and AIDS.

## **1.2 Influence of EDC Contamination on Wildlife and Ecosystems**

EDCs probably contribute to the decline in some wildlife populations such as fish, alligators and birds (Guillette et al., 1996; Johnstone et al., 1996; Vos et al., 2000). Indications are that wildlife in South Africa is being adversely affected by EDCs. Egg shell thinning in bird species have been observed, as well as feminization of fish and amphibian species.

## **1.3 Economic and Industrial Implication of EDC Contamination**

South Africa is a signatory to the Stockholm Convention on the control of Persistent Organic Pollutants (POPs) ratified during the World Summit on Sustainable Development in August 2002 and signed September 2002 (<http://www.pops.int/documents/signature/signstatus.htm>). Parties undertake to limit and control the release of persistent organic pollutants in the environment. The National Government through several National Departments, such as Department of Water Affairs and Forestry (DWA), Department of Health (DOH), Department of Environmental Affairs and Tourism (DEAT), Department of Trade and Industry (DTI) and Department of Agriculture (DOA), is under the obligation to initiate programmes so that a process of cooperative governance may be introduced in order to enable South Africa to honour the Stockholm Convention obligations.

In a previous WRC Study (1402/1/08) it was indicated that EDCs were present in four selected sites in South Africa. These sites were not chosen at random, but were selected using certain criteria (WRC Report KV 143/05, Volume 1 of this report). Although this is by no means a reflection of the situation in the entire country, it is an indication that these compounds could pose a detrimental health effect in the ecosystem. Observations made in another WRC study (WRC Report 1505/1/07) where animals such as the eland, certain bird species and other aquatic animals were studied, indicated ED effects.

The limited water resources of South Africa, the limited health budget, the likelihood of significant pollution by industry, the lack of proper waste control and the need to use DDT for malaria vector control, emphasize the need for timely measures to be taken by the authorities.

## **1.4 Conclusion and Recommendations**

A strategic research plan was developed and implemented (WRC Report KV 143/05 and WRC Report 1402/1/08). During the implementation of this plan certain new issues were raised that also needed attention. It soon became clear that our current chemical analytical methods at that time were not suitable for this work, because the detection limits were too high. We did not have the capability to determine certain important EDCs such as hormones, dioxins and alkylphenols. We also realised that we cannot determine EDCs by doing chemical analysis alone. The need for activity testing became important and development of biological/biochemical methodology was needed. Such methods were available overseas, but they had to be implemented and verified in this country. Some

of these issues were addressed and implemented during this phase of the Strategic Plan. After completion of the first phase of the EDC research programme, because occurrence of EDCs was established, it now became necessary to manage the pollution problem.

#### **1.4.1 Aims of the project**

It is important to revisit and evaluate the initial aims and investigate future research needs. The aim of this project therefore is to evaluate and review the preceding strategic plan (Volume 1), as well as the implementation of recommendations from Volume 2 of the EDC Research Programme to ensure that the research programme addresses all the relevant factors and that a more comprehensive picture of the ED effects on humans and wildlife could be obtained.

#### **1.4.2 Objectives**

- The outcome of the Programme should provide relevant and sufficient information to the government so that a policy may be developed to manage the EDC contamination problem.
- At the same time it should provide for the development of analytical tools that scientists can use to determine the levels and source of EDCs in water resources.
- A revised strategic research plan needs to be developed to address the current needs of the stakeholders.

## **2. METHODOLOGY**

From the onset of the WRC EDC research programme, it was deemed necessary to involve all the different role players in the water research field to establish their needs and to identify the knowledge gaps in order to formulate a rational research programme. This was done by means of workshops attended by all stakeholders. A framework for future research to meet the needs of the stakeholders has been developed according to the needs expressed by the stakeholders (Volume 1) and also by taking new international trends into consideration.

### **2.1 Needs and Gaps Analysis**

#### **2.1.1 The Morgenson Stellenbosch Workshop 2003**

At this two-day workshop, the results of previous research projects relating to EDCs were presented. Role players were then requested to define their current and future needs and to identify any strategic knowledge gaps. Every group was also requested to formulate proposals for research projects to fill the knowledge gaps identified. Strategic plans for the future of EDC research were also developed. The role players were identified as being the following:

- Government Departments
- Water suppliers
- The human health group
- Environmental group
- Industry

## 2.1.2 The Pumulani Pretoria Workshop 2005

This workshop was held as a follow-up to the Morgenson Workshop (see Volume 1 and 2). After evaluating the research done during the past year, the stakeholders were asked to *revisit* their needs and indicate whether those knowledge gaps still exist in order to compile a research plan for the following years. The results of this workshop may be summarized as follows:

### 2.1.2.1 Needs of Government Departments (DWAF)

#### *Needs:*

The need identified was to have the necessary information to develop a management policy and provide guidelines to stakeholders to ensure water safety.

#### *Knowledge Gaps:*

The following gaps were identified and briefly discussed:

- **Risk assessment for humans and wildlife**  
A **framework for risk management** is needed, including hazard identification, exposure assessment, dose-response data and **quantifiable** levels to develop guidelines. This includes:
  - **End points:** What are the end points, i.e. the ultimate effects of the chemical on the organism?
  - **Hazards:** A description of the hazard, its potential effect and end result, to reach some degree of consensus opinion among the South African scientific community, should be included. This should be a semi-quantitative description for both human use and impact on the ecosystem.
  - Studies to determine **dose-response relationships** for the various chemicals (whether exact or semi-quantitative) are needed as a base for all risk assessment studies. The existing dose-response curves in EDCs are not typical dose-response curves. They are not linear, but u-shaped or reverse u-shaped curves.
  - **Exposures:** Two important questions need to be addressed: how would the test organism respond as an independent variable in the dose-response and how would the toxicant present itself in the environment with respect to both humans and the environment? A surrogate organism may be needed to be measured in the background (along the lines of TDS or electrical conductivity). A comprehensive description is needed of the exposure results so that DWAF can translate the information into source and land-use management terms.
- **Surveillance programme**  
A **surveillance programme** linked to a **knowledge management** process is needed. Unless an efficient surveillance programme is introduced, not enough data will be generated for risk assessment and modelling. It is therefore proposed that a programme is developed which would make provision for the implementation of a comprehensive surveillance programme. Based on the data collected, risk assessment models for humans and wildlife

may then be developed, followed by the formulation of guidelines for the protection and management of the country's water resources.

- **Management tools (Guidelines)**

South Africa's water resources need to be managed according to catchment management plans and strategies. This would imply that guidelines need to be developed in support of these management strategies. DWAF is currently in the process to review and extend the **1996 Water Quality Guidelines** and this could provide an opportunity to incorporate EDCs in the guidelines. However, **numbers (quantitative data)** are needed for the development of appropriate and relevant guidelines. The results of risk assessment studies will provide valuable data towards guideline development. However, there are other approaches that may be followed. DWAF for example, needs data to use in the development of monitoring programmes and identifying of 'hot spot' areas. The National Water Act makes provision for the classification of water resources on the basis of ecological status and lawful use. This means that what is needed is not a single value (i.e. yes/no). What needs to be established is whether there is a **variable scale of concern** and to decide how to fit that scale into the classification system and ideally align it with values that are already in place. Drinking water standards have the classification of 'ideal' at one end and 'lethal' at the other end of the scale. Although it might not be immediately possible, the aim should be to work towards a variable scale with benchmarks at various points that the community believes are tenable and scientifically defensible. The same principle applies to the aquatic ecosystem. The data generated through previous projects and those that are yet to come, should fit into that framework.

### ***2.1.2.2 Needs of drinking water suppliers***

#### ***Needs:***

The primary need is to conform to government guidelines and to supply water fit for human consumption to the public. National guidelines for drinking water quality already exist, but do not make provision for EDCs. It will now also become essential to determine the quality of *raw water* before any treatment could be applied. Existing treatment processes are in any case not sufficient to effectively remove any EDCs from raw water and new technology will be required.

#### ***Knowledge Gaps:***

- **Risk Assessment**

There is a need to look at **total exposure**, including not only drinking water but also water used for irrigating food crops. Thus, the total food chain needs to be studied. It may be possible to clean up all the drinking water, but EDCs may still end up in food through irrigation. All environmental pollutants will ultimately find their way into the water resources, and in order to manage total risk, assessing the effects that exposure to those pollutants will have on human and wildlife through the water, will be of the highest priority. However, the quality of *drinking water* will be of major concern to all suppliers of drinking water.

- **Treatment**

- **Removal treatment.** If a guideline is set, how do water suppliers implement it to remove the EDCs? Treatment processes that would remove the chemicals should be investigated, as well as the levels that could be removed and at what cost. Current available technology should be investigated and proposals made for the upgrading of existing plants if necessary.

- **Suitable and Appropriate Technology** is required. If a biological test is undertaken and a positive result is obtained, what does it mean? How should the water supplier respond? Should the plant be closed, or an activated carbon plant installed at a cost of millions of Rand? It will therefore be essential to provide operators of water treatment plants with clear instructions on how to interpret analytical results and what corrective steps should be taken in the light of those results. At all times, clear and direct communication between operators and analytical staff will be of the utmost importance.

- **Management tools**

- **Guidelines**, clearly stipulating the acceptable numerical values for chemical pollutants found in drinking water, will always be the ideal management tool. The question remains what effects organic pollutants will have on humans, and what the guidelines should be, according to a risk-based approach, for exposure of humans to these compounds. Again, guidelines should also advise operators of the various options available for treatment of raw water in order to successfully remove one or more EDCs.

- Although a complete set of water quality guidelines could be regarded as the most important tool in the proper management of drinking water supplies, it will be of no value if reliable analytical results are not available. It is therefore important that a **protocol for the sampling, handling and analysis of water samples** should be developed and adhered to. Guidelines for the interpretation of analytical results will obviously also be essential.

- **Remedial action**

- Most countries do not have the problem of recycling of water as is practiced in South Africa. With an annual rainfall below the global average, effluents from wastewater treatment plants are often redirected into low flow rivers to be used again by communities downstream. Studies have found that drinking water treatment systems can remove 80-90% of chemical pollutants. As South Africa repeatedly recycles its water, chemicals (e.g. hormones) will thus accumulate in the water if only 80% of hormones are removed in every treatment cycle. South Africa clearly needs other **remedial actions** and more studies on the ultimate consequences of recycling of drinking water need to be done.

- **Human resource capacity and laboratory facilities:**

- The **capacity** of staff working in treatment facilities and laboratories is a problem (refer to Volume 1). In a small survey undertaken by Rand Water on 15-20 water works, a total lack of capacity was encountered, and operators were struggling even with the chlorination process and to measure turbidity, specifically at the smaller treatment plants. Large treatment plants are in a

better position, as they have the technology and technical staff to establish good laboratories for reliable biological and chemical analyses. The dilemma for smaller water treatment plants is whether to establish their own analytical facilities or to send the samples away for testing. Large water suppliers require the skills of chemists and microbiologists, but these scientists tend to remain in their positions in the laboratory on average for only 1.5 years before moving into management. Many people can perform the basic analyses but are unable to interpret the values found. It is also of the utmost importance that Water Boards reconsider remuneration levels for skilled staff to ensure **retention of skills**.

### 2.1.2.3 Needs of ecosystems

#### *Needs:*

South Africa has obligations in terms of the International Convention on Biodiversity to protect its own **biodiversity**. This includes the sustainability of both biophysical and water quality biodiversity with the purpose of protecting different biodiversities in and around our water bodies.

#### *Gaps:*

- **Assessment of the problem**
  - No information exists about the **link between ecosystem and human health**. EDCs are part of a whole suit of toxicants which may be present in the aquatic environment. In order to develop relevant guidelines for the management of aquatic ecosystems, baseline data as well as dose-response information for a wide variety of organisms need to be obtained.
  - Preliminary tests carried out on **invertebrates** suggest that the effects of EDCs on invertebrates could be linked to the effects that EDCs may have on the human endocrine system. Extensive research will be required to confirm this link.
  - Ecosystem health starts with **individual health** of an organism. To assess the health of the individual in the population, an index of whether the individual is reproducing is needed. The EDC effect is not only about mortality – EDCs may also have an effect on one or more of the other parts of the endocrine system. The switch of genes early on only affects the adult. It is also essential to assess both individual and population health. The ecosystem is complex, with complex food chains. It has been recorded that some familiar species are no longer encountered in the ecosystem where we used to find them (e.g. frogs at Rietvlei Nature Reserve, a heavy polluted aquatic ecosystem). However, we still know very little about the life cycle of indigenous species, and even less about their reaction when exposed to pollutants. It is therefore clear that, in order to understand the health of animals in an ecosystem, we need to know and understand the **physiology** of those animals.
  - **Population studies**. It is already possible to identify certain ecosystems that could be targeted to establish whether they are healthy or not. There are opportunities for South Africa to get involved in comparative work with research undertaken on water systems in other parts of the world.

#### 2.1.2.4 Human health needs

##### *Needs:*

There is a need to establish the risk of EDC contamination to human population for management and policy development.

##### *Gaps:*

- **Risk assessment**
  - A **South African human health risk assessment model** for EDC exposure, which will also make provision for a mixture of chemicals, needs to be developed. The composition of the various **mixtures of chemicals** encountered is different in different areas. The effects of EDCs at below detectable levels are not known. This risk assessment should be undertaken not only with respect to chemicals used and produced locally, but also with respect to exposure to pollutants in the **global environment**. The focus, however, should be on chemicals that are relevant to South Africa. This could be investigated through the use of **sentinel animal species**. In South Africa, we are fortunate to have animal species that can be used to provide links to humans and their response to exposure to EDCs. The gaps with respect to our knowledge of groups of chemicals include **veterinary compounds**, on which little research has been done.
  - **Epidemiological studies** on the effects of EDCs in South Africa is not an easy task and is mostly research undertaken in the final phase of an investigation. However, to move to **fundamental research** and get some answers that we would not get through epidemiology (such as toxicogenomics at pre-clinical levels), would be moving a step forward. In this area capacity needs to be built.
  - There is a need for research in **immunology**, and not just in the areas of the reproductive and thyroid systems. South Africa tends to focus on applied immunology. Immunological studies are much needed on the African continent, where there are severe problems of immune deficiencies due to malnourishment, the rising HIV and AIDS occurrence and other causes.
- **Remedial action:**

The aim is to **limit exposure** of all organisms to EDCs. If we can reduce EDC levels in water, we could limit the risk, not only to the environment, but also the ultimate effects on the genetics of humans and other ecosystem populations. For this, knowledge of the fate and behaviour of chemicals in the environment as well as in wastewater treatment facilities is required.
- **Socio-economic factors:**

**Socio-economic factors** need to be part of the study description. In epidemiological studies, issues such as daily food intake should be addressed in the design of the study. Mexico, for example, managed to stop using DDT by addressing issues of water and sanitation through surveillance of the occurrence of DDT in the environment. Such studies in South Africa could contribute to reducing the use of DDT against the malaria vector, thereby complying with the requirements of the Stockholm Convention.

### **2.1.2.5 Industry needs**

#### ***Needs:***

Industry is concerned about the **impact** they have on the **environment**. They also have to conform to regulations set by DWAF, DEAT and DTI.

#### ***Knowledge Gaps:***

Industries need relevant and credible data, risk assessment models and remediation options and guidelines for management of effluents to prevent pollution of water resources.

### **2.1.2.6 Needs of local government**

#### ***Needs:***

Local government needs to conform to national government guidelines. Therefore, comprehensive guidelines on the management of the whole ecosystem would be required.

#### ***Knowledge Gaps:***

- **Technologies** for treating sewage to conform to the guidelines. Where current treatment processes are not sufficient to remove pollutants, guidance on the introduction and operation of alternative processes need to be available.
- **Hormones** have been found in reclaimed water and in environmental water resulting from the discharge of sewage. The risk is not fully understood. Screening tests also revealed various levels of hormones in raw drinking water. In some cases sewage sludge is directly discharged into rivers. It is not known what happens when people drink water from those rivers regarding the effects of EDCs, but people do contract diarrhoea and other microbial pathogen-related diseases.

### **2.1.2.7 Animal health needs**

#### ***Needs:***

There is a need to protect wildlife and to improve the quality of livestock. To improve the quality of both livestock and animal products, water of good quality is essential.

#### ***Knowledge Gaps:***

- Previous studies (Barnhoorn et al, 2002) already indicated that EDCs have detrimental effects on the reproductive organs of certain wildlife species. More information on the effects that EDCs may have, not only on wildlife, but also on livestock, is essential.
- It is recommended that **veterinary toxicologists** get involved in the research (i) to give credibility from an ethical point of view and (ii) not to discount the role of infectious diseases in the probable adverse effects of EDCs.
- The importance of **surveillance of wildlife** should not be overlooked. The organisations involved in the management of wildlife sanctuaries recognize

that they have to establish conservation hand in hand with local communities, and that water sources for communities and wildlife have to be shared. This would thus lead to shared exposure to EDCs present in the water. The wildlife industry also needs to be investigated, because wildlife are important as part of the ecosystem and they are not only exposed to EDCs in water all the time. While there is no harm in doing surveillance of terrestrial animals, this should not be the only focus, but could serve as an indication of ED effects on other species as well.

- From a strategic point of view, the effects that **inorganic chemicals** may have on wildlife and livestock should not be overlooked. It is also essential to study and describe the **background factors**, bearing in mind that there are naturally occurring EDCs which may also affect both human and animal health.
- What we see in case studies and present with thyroid, immune suppression and reproductive factors is the **effect of chemical mixtures**, with **local variability**.
- From a physiological point of view, one would want to see an **integrated approach**, although this is not always possible.

### 2.1.3 Summary of priority knowledge gaps needed to satisfy requirements of stakeholders

When asked to prioritise needs (gaps), the following list was common to all stakeholders:

- **Reliable and credible data on occurrence and magnitude of EDC pollution.**
- **Information regarding the fate and behaviour of EDCs in the environment and in the human body.**
- **Models for risk assessment.**
- **Relevant and affordable analytical methods with quick turnover.**
- **Facilities for analytical procedures.**

The first three abovementioned needs can be classified as management tools. The remaining two needs are tools for scientific project execution.

## 3. A FRAMEWORK FOR FUTURE RESEARCH IN THE EDC PROGRAMME

As a result of combining the needs identified by stakeholders from various sectors with the overall gap in available knowledge, it is proposed to develop a comprehensive research programme to guide future research into the effects EDCs may have on both humans and animals. To achieve this goal, it is necessary to address the problem at two levels:

- **Fundamental research: providing a scientific base for data acquisition and policy development**
- **Applied research: development of management tools**

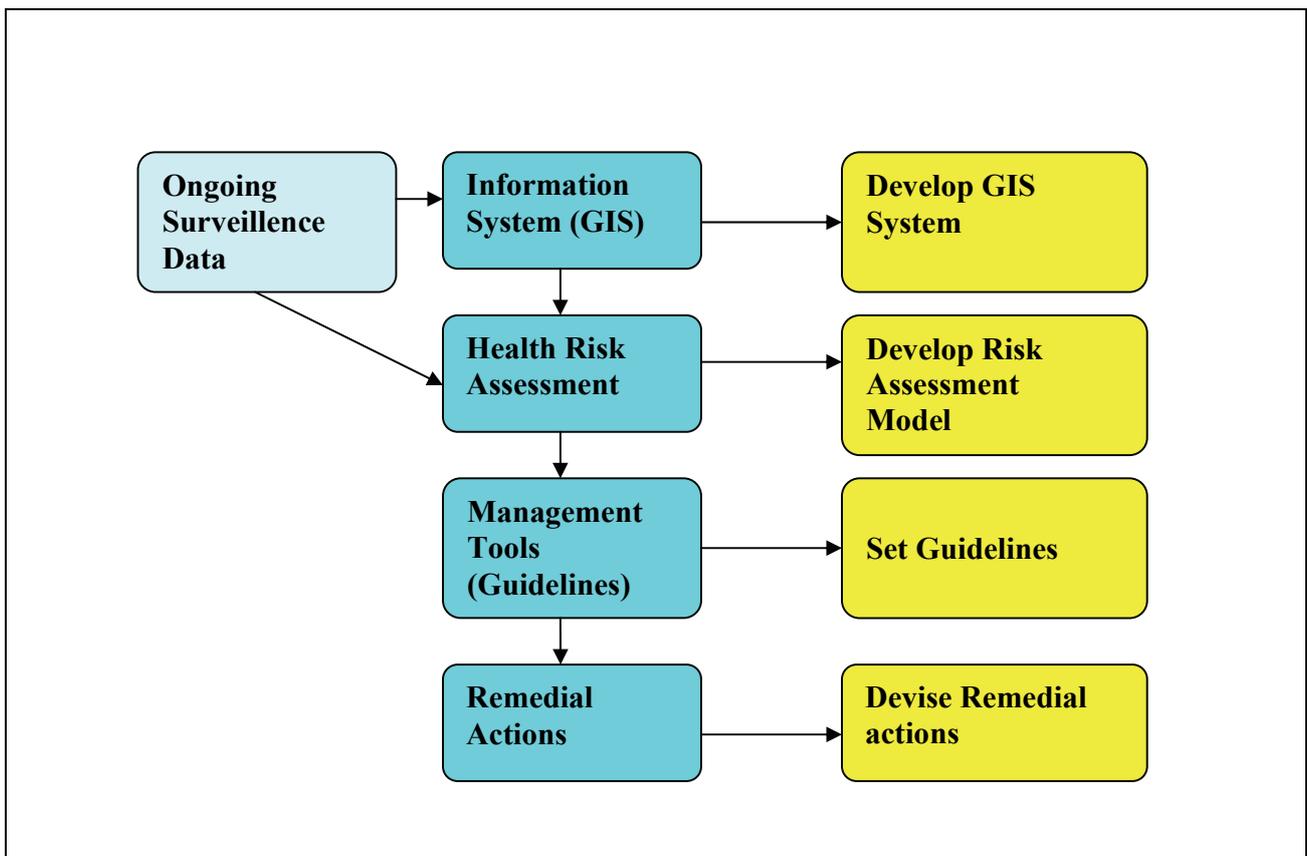
### 3.1 Fundamental Research (Policy Development)

Although EDCs are not a new problem, it is only during the past 12 years that scientists have become aware of the extent to which we are exposed to these chemicals. Water is only one of the exposure pathways, but water pollution is a very sensitive issue. The consumption of EDCs has become part of our lifestyle. Unfortunately there is no single test to determine the presence of EDCs in water. A toolbox of tests is required to measure the presence and extent of EDC pollution in water. The mechanism of the working of EDCs on the different hormonal systems in the body is not yet fully understood and the fate and behaviour of the EDCs in the environment is not known. Most of the funding in previous research projects was spent on developing methodology for determining the presence and activity of EDCs in our water systems. It is now necessary to move on – the country needs a clear policy to address the pollution of EDCs in our water systems. The proposed research programme should provide a sound base to develop such a policy. A summary of the EDC research programme (Fundamental Research) for the next 5 years is presented in Figure 3.1.

#### FUTURE RESEARCH PROGRAMME

**POLICY DEVELOPMENT**  
(Fundamental research)

**ACTIONS**  
**NEEDED**



**Figure 3.1: Framework for future research**

### **3.1.1 Actions needed for policy development:**

- In order to develop a policy for the control of EDCs, comprehensive human health and environmental risk assessment studies are of cardinal importance in order to obtain reliable and credible data. To acquire sufficient data to undertake human health risk assessments, an ongoing surveillance programme is needed. In order to produce this data, research is still needed on methodology to detect certain chemicals in water, sediment and biological tissue. Detection of EDC activity is still in the development stages worldwide and requires more research in this country. Very little data exist on the occurrence of EDCs which are not normally regarded as toxicants (such as natural and synthetic hormones) in water systems. Furthermore, no data is available on the occurrence of veterinary substances in water. These substances, of which some are growth hormones, are used in large quantities at feed lots, chicken farms and piggeries.

#### **Research in progress:**

The following research has started, earlier than anticipated, resulting from the results of the implementation of the initial Strategic Plan (Volume 2, WRC Report 1402/1/08):

- Research has started on the measurement of EDCs in the environment by studying certain sentinel species. South Africa has a vast resource of indigenous species which may be used in such a study. However, much is still unknown about the physiology of these animals (WRC Report 1505/1/07).
- A consultancy to develop a risk assessment protocol for EDCs in water (KV 206/08).
- Research on the presence of EDCs in drinking water treatment processes (WRC 1532/1/08).

#### **Proposed research:**

The following research projects are proposed for the next few years to address the knowledge gaps identified:

- A study on the impact of veterinary drugs on water systems near feedlots
- The compilation of a manual on the analysis of EDCs in water, sediment and biota. This is necessary for the production of credible data and will also ensure that data produced by different laboratories are comparable. Apart from analytical procedures for activity testing and chemical analysis, the manual should also address issues such as sampling, calculation of results and statistics.
- A study to investigate the mode of action of selected chemicals on the hormonal systems of the human and animal body.
- A study to investigate the development of a risk assessment model or framework for the ecosystem.
- A model for human health risk assessment should be developed after the protocol, because the existing models use the onset of cancer as an endpoint. The endpoint, i.e. the ultimate effect for EDCs, still has to be set. Very little is known about the dose-response curves for EDCs. For a comprehensive risk assessment exercise, research is needed not only on the reproductive effects of

EDCs, but also on the effects on the nervous system, the thyroid function and the immune system. Not only is research needed on the mother compounds, but also on the effects of the breakdown products. At first, the current and available models for human health and the ecosystem have to be scrutinized to seek models that would be applicable for South Africa. If no suitable model(s) are found, further research should be undertaken to develop relevant models for South Africa.

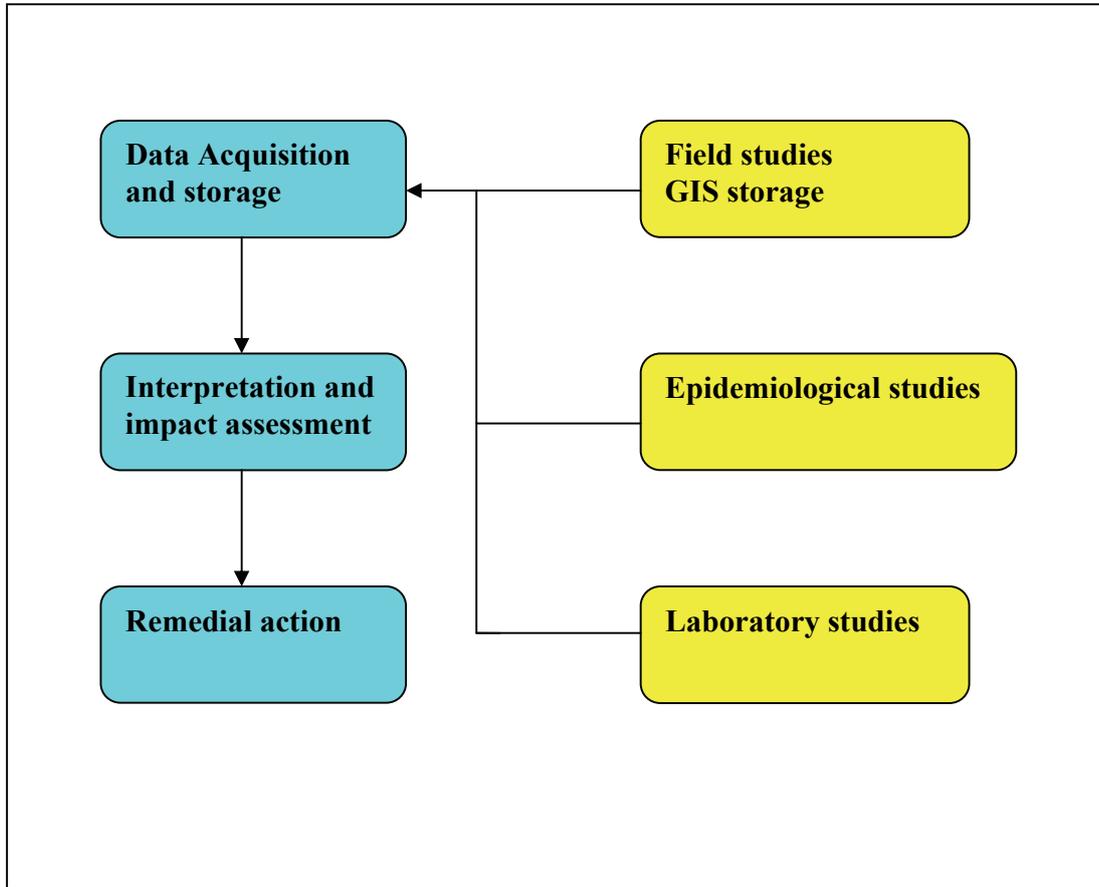
- Guidelines regarding levels of occurrence of EDCs in water resources need to be developed to ensure the safety of the water resource to the population. It will also provide regulations for the water suppliers to use. This, however, can only be done once a reliable risk assessment model is in place, and most probably will be a natural product of the framework.
- Remedial action needs to be taken in problem areas. The water systems in South Africa are very dynamic and each region has its own problems. This makes modelling extremely difficult. Monitoring water resources and the analysis of samples are costly and may be limited if suitable models can be found.
- Most of the research done was focused on the reproductive system of males. Only limited research is done on the effect of EDCs on *females* and on other endocrine systems such as the neurological system and the thyroid function. It is, however, necessary to take all of the effects of EDCs on living organisms into consideration, therefore the immuno, thyroid and neurological systems also need to be investigated in the programme.

### **3.2 Applied Research**

Research on the impact of EDCs generated by agriculture, industry and human pollution should be approached in an alternative way. Field studies will be necessary in selected vulnerable areas in order to determine the influence of agricultural/industrial chemicals with EDC activity in water systems. The following steps need to be taken (Figure 3.2):

**IMPACT ASSESSMENT  
(Applied research)**

**ACTIONS  
NEEDED**



**Figure 3.2: Framework for applied research**

**3.2.1 Agricultural activity**

Research that would be needed to understand the impact of agriculture on water resources, food security and production, are the following:

- A scoping study on the potential impact of agricultural chemical substances that would include the type of crop for which individual substances are used. (Each crop has its own set of chemicals registered for use). Such a study will include:
  - Determination of the chemicals used on the crop.
  - Selection of chemicals with ED properties.
  - Collection of data on the volumes used and frequency of application. This should include a study of the geological make-up of the area to determine whether chemicals may reach rivers or dams and the identification of possible problem areas.
- The risk to the ecosystem and wildlife could be done through a laboratory study to determine the effect of mixtures of pesticides and industrial chemicals in water on fish, tadpoles and small mammals.
- Recommendation for remedial/management actions should be made after such a study.

### **3.2.2 Industrial and mining activity**

Each of these sectors would have their own input and effect on the environment and water resources. Knowledge gaps to be addressed are the following:

- A survey needs to be done on the type of industry present in the area, the raw material used, the waste products generated as well as the disposal of wastes into any catchments in that area. For such a study it is needed that the chemicals with ED properties which are used and produced by the industry, as well as the by-products formed during the production, including the emission of volatile substances, should be investigated. Cleaning agents must also be taken into account. Special care should be taken of run-off water in cases of mining activity. Such a study will include:
  - Collection of data on volumes released in water systems as well as the geological make-up of the area to determine whether chemicals may reach rivers or dams.
  - Determination of the risk to the population and wildlife.
  - Identification of possible problem areas.
- Recommendation of remedial/management actions should be included to develop a management strategy for catchments in that area

### **3.2.3 Pollution due to human presence**

Humans and households are also contributing to the EDC pollution of water resources and the environment. Research is therefore needed as follows:

- A survey needs to be done on human communities located near water resources, especially where sewage treatment plants or sewage disposal areas are closely located to these resources. The presence of hospitals and clinics in the area has to be taken into account for their specific pollution products. Monitoring the surface and groundwater systems utilized by informal settlements for EDC activity and hormones is specifically needed. Determination of the risk to the population and wildlife, and identification of possible problem areas should be followed by recommendations for remedial/management actions.

### **3.2.4 Methodology for a comprehensive EDC study on catchment scale**

It is recommended that these studies should be done in three phases to ensure that all the needs mentioned are addressed, and should include all aspects discussed in 3.2.1, 3.2.2 and 3.2.3 above. This should include:

- Identification of potential problem areas in relevant catchment areas.
- Intensive study and monitoring of the identified potential problem area that would impose the highest risk.
- Guideline development for risk assessment and remedial actions and available options. Recommendations should be generic and applicable in other areas, albeit with small adaptations.

#### ***3.2.4.1 Identification of potential problem areas***

It is recommended that the country be divided into regions – the catchment management areas would be the most sensible division. Above-mentioned

information may be recorded and supplied by the catchment management area manager. Only crops cultivated on areas larger than 2 hectares need to be taken into consideration, while the number of animals farmed on a specific test site should be more than 100. Only industries with a turnover of more than R50 000/year need to be taken into account. Only formal mining needs to be included in the study.

Information regarding the geological make-up of the areas may be obtained from the Geological Survey.

#### ***3.2.4.2 Intensive study of potential problem areas***

Once potential problem areas have been identified, a limited surveillance study should be undertaken in that area to determine EDC activity and potential sources of pollution. It is recommended that the water systems in potential problem areas are initially monitored for EDC activity using the Yeast Screen Assay. Should the results be positive, a more intensive surveillance of these chemical compounds may be needed. This will be a very complicated study, as agricultural chemicals, industrial chemicals and hormones may be present at the same time in the water resource and without extensive chemical analysis it would be impossible to determine the cause of the EDC activity.

#### ***3.2.4.3 Guideline for risk assessment and plans for remedial action***

A generic guideline for remedial action can be put in place once the pollutants have been identified. A human health risk assessment may be necessary to establish the risk to the population.

### **3.2.5 Proposed time frame for the comprehensive study:**

An ideal time frame for the proposed framework for the extended research programme for EDCs is given in Table 3.2.5.

**Table 3.2.5: Proposed time frame for EDC programme**

	2006-2007	2007-2008	2008-2009	2009-2010
Surveillance	X	X	X	X
Information Storage	X	X	X	X
Risk assessment		X	X	X
Remedial action			X	X
Policy development			X	X

**Note: This proposed time frame is highly optimistic and will most possibly extend beyond 2010**

### 3.3 Selection of Research Projects to Satisfy Needs of Stakeholders

In selecting research projects for the following 5 years it must be kept in mind that the aim of the research programme is to provide a sound scientific base to develop a rational policy to manage the EDC pollution problem on a national scale and at the same time assist scientists to develop management tools to measure the pollution and provide solutions to minimize the effect of the pollution on humans and wildlife. The following factors need to be taken into account:

- The research project must be aimed to satisfy the needs of the stakeholders.
- Projects must be relevant to the South African situation.
- Projects should address an area/situation not previously studied, or an area where more information is needed.
- The research must fit into the terms of reference of the WRC.
- The research has to conform to the current policy of the Department of Science and Technology (DST).

### 3.4 Remedial Action

At the stage when remedial actions need to be selected and implemented, it may be necessary to develop different remedial actions for each problem area. These actions need to be developed in cooperation with the organisations, industries, farmers or population of the area.

### 3.5 Education and Knowledge Dissemination

- The need to **inform the public** and disseminate information is most pertinent to human health, but not exclusively related to human health.
- A cautionary note on **conclusions and recommendations** of reports: researchers have to realise that once committed to paper, the information presented in a report should be qualified from the point of view of **physiological significance**, as well as **contextualized**, *even though the information may be confidential*. Once a report has been printed and published, the information will then be in the public domain. This must always be based on science and only the scientific value should be taken into account. Research on EDCs should be regarded as sensitive and the results should be scientifically sound and care should be taken to present it as such.

### 3.6 Funding

In South Africa, all scientific research is coordinated and controlled by the Department of Science and Technology (DST). In order to qualify for funding for research projects, EDC-related research has to be undertaken according to the strategies and policies set by DST. In collaboration with the WRC, the approach followed should at all times be comprehensive and involve all the other relevant role players, i.e. Departments of Environment Affairs and Tourism, Trade and Industry, Agriculture, Water Affairs and Forestry, Health and Science and Technology, as well as universities, the CSIR, and the new research chairs being established at universities through the National Research Foundation (NRF).

There is a need for official collaboration and an integrated approach between the NRF, DST, WRC and DWAF, otherwise the impact of the research will remain limited. There is also a need for

strategic planning to involve all stakeholders and interested parties. The programme needs to be packaged according to the various components of the framework and since this is groundbreaking research, leadership would be most important. Surveillance programmes (e.g. the fish quota programme) have been recognized as research programmes in South Africa for the first time. The time is right but the journey is complex and the competition is high. However, excellent research has already been done to position the programme.

### **3.7 Conclusions**

- The first phase of the WRC programme on EDCs was implemented successfully. It was proved that EDCs are present in our water systems and that agricultural chemicals, industrial chemicals, pharmaceuticals and natural hormones are responsible for the ED activity. The need for a national policy to manage the problem has now been expressed by all stakeholders.
- An extended research plan for the WRC's EDC programme is proposed. This includes development of management tools such as data acquisition, information storage and research into areas where information is lacking.
- More fundamental research needs to be done on the effects of EDCs on the neurological system, the immune system and the thyroid function of the human body.
- The focus of the plan is aimed at addressing the needs of all the stakeholders by proposing research projects to address the knowledge gaps identified at two workshops.
- Although South Africa has the scientific capability to conduct the proposed research, it is doubtful whether the capacity exists to handle large numbers of samples. Analytical capability is essential for the execution of all research projects.

### **3.8 Recommendations**

- All future research should be aimed at the management of EDC pollution in South African water systems, i.e. the development of policy and management tools. The research projects of the WRC should be such to lead to policy development and help stakeholders to minimize pollution in water systems.
- For the implementation of the programme it is necessary that the researchers should be given the best support available. It is therefore important that facilities should be provided to do the research and to develop new and appropriate analytical techniques. This research should focus on the analysis and determination of both EDC activity as well on chemical analysis of aquatic samples. The researchers should also negotiate and collaborate with other organisations such as the CSIR and SABS. Universities should be encouraged to form self supporting institutes at their facilities in order to provide an analytical service to researchers and to the public. This could create opportunity to career building and job creation for students after the completion of their studies.
- It is not within the framework of the WRC to establish a monitoring programme. The WRC could, however, support the initiative of DWAF in their effort to put such a programme in place.
- EDC research is expensive and alternative sources of funding should be found to supplement the funding of the research.
- Capacity needs to be built, both organisational and human resource capacity. During the execution of the first part of this programme several post graduate students were trained and involved in the projects. They left the field, however, because they could not find EDC related

jobs. It is therefore important to address this and to keep the capacity within this field of interest and in the country.

- It is in the interest of the country that the WRC's EDC research programme should continue until a management strategy of EDCs is in place and guidelines for remedial action has been developed.

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