Global Water Research Coalition

Endocrine Disrupting Compounds

Knowledge Gaps and Research Needs

Global Water Research Coalition

IWA affiliate

Endocrine Disrupting Compounds

Workshop of Knowledge Gaps and Research Needs of EDC in Water Systems

Global Water Research Coalition: Cooperation for worldwide water knowledge, innovation and progress

GWRC is a non-profit organization that serves as the collaborative mechanism for water research. The product the GWRC offers its members is water research information and knowledge. The Coalition will focus on water supply and wastewater issues and renewable water resources: the urban water cycle.

The members of the GWRC are: the Awwa Research Foundation (US), CRC Water Quality and Treatment (Australia), Kiwa (Netherlands), Sues Environment- CIRSEE (France), Stowa - Foundation for Applied Water Research (Netherlands), DVGW – TZW Water Technology Center (Germany), UK Water Industry Research (UK), Veolia - Anjou Recherché (France), Water Environment Research Foundation (US), Water Research Commission (South Africa), WaterReuse Foundation and the Water Services Association of Australia.
These organizations are all in charge of a national research program addressing the different parts of the water cycle. They have provided the impetus, credibility, and initial funding for the GWRC. Each brings a unique set of skills and knowledge to the Coalition. Through its member organisations GWRC represents the interests and needs of 500 million consumers.

The Global Water Research Coalition is affiliated with the International Water Association (IWA). The GWRC was officially formed in April 2002 with the signing of the partnership agreement at the International Water Association 3rd World Water Congress in Melbourne. With the US Environmental Protection Agency a partnership agreement was signed in July 2003.

Endocrine Disrupting Compounds

Workshop on Knowledge Gaps and Research Needs of EDC in Water Systems

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Prepared by:

Water Research Commission (South Africa)

In cooperation with:

Kiwa Water Research (Netherlands) and

TWZ – Water Technology Center (Germany)

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Global Water Research Coalition

Alliance House
12 Caxton Street
London SW1H 0QS
United Kingdom

Phone: + 44 207 654 5545
www.globalwaterresearchcoalition.net

Disclaimer

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PROJECT TEAM:

Lead agent: Mrs. Annatjie Moolman, WRC (South Africa)
Mr. Leo Puijker, KIWA (Netherlands)
Dr. Frank Sacher, TZW (Germany)
Mr. Frans Schulting, GWRC (Netherlands)

MEMBERS:

Mr. John Churchley, Severn Trent Water (UK)
Prof. Ian Falconer, CRC water Quality & Treatment (Australia)
Dr. Maire-Laure Janex, CIRSEE (France)
Dr. Djanette Khiari, AWWA RF (USA)
Ms. Jami Montgomery, WERF (USA)
Mr. Mark Pascoe, IIWA (UK)
Dr. Cora Uiterlinde, STOWA (Netherlands)
Mr. Gordon Wheale, UKWIR (UK)

CO WORKERS:

Mr. Pieter van Zyl, SABS South (Africa)
Prof Egmond Rohwer, University Pretoria (South Africa)
Mr. Sebastiaan Jooste, IWQS (South Africa)
Mrs Ansie Burger, WRC (South Africa)

GLOSSARY OF DEFINITIONS

Endocrine Disrupting Compound: (WHO definition)
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 organism, or its progeny, or (sub) populations.

Source water:
Source water is defined as water coming from a natural source i.e. water from rivers, dams, streams and fountains. Borehole water is also included in this category.

Drinking Water:
Under the term drinking water is understood water which is treated and intended for human consumption.

Tap Water:
This is water taken at the consumer point of the treated water distribution system.

Receiving water: This is water in a river or other body of water into which an effluent is discharged.

Surface water: This refers to river water from the source through to the drinking water intake.

Waste Water:
This is defined as:
1. Untreated wastewater: Water used and/or polluted by humans by agricultural or industrial activity.
2. Treated wastewater: Water at the exit of a purification plant.

Raw Water:
Untreated water.

NOEL:
Acronym for 'No observed effect level'.

ELISA:
Acronym for 'Enzyme-linked Immunosorbant analysis'.

EXECUTIVE SUMMARY

There has been increasing concern regarding substances in the environment that could impact on the endocrine systems of wildlife and man. The data that initiated the concern relate to fish, amphibians, reptiles and, to a lesser extent, birds exposed to anthropogenic chemicals through the aquatic environment. Significant changes were observed in the reproductive organs of alligators and turtles exposed to a mixture of persistent pesticides in a Florida Lake while changes in the reproductive organs of male fish exposed to treated sewage effluent were also observed. The changes were shown to be mediated through effects on the endocrine system, which is a complex hormonal mechanism for control of the development and physiological status of animals, particularly vertebrates. These findings also resulted in concern for possible impacts on humans through exposure to endocrine disrupting substances from drinking water derived from primarily from surface sources.

In the light of this global concern regarding the potential threat of endocrine disrupting substances to aquatic life and drinking water, the board of the Global Water Research Coalition (GWRC) determined that this subject would be the first priority for their collaborative research. This was considered to be particularly appropriate in view of the global nature of the potential problem and because of the number of research projects that were being developed by water industry and water research bodies in many parts of the world.

- A number of questions needed to be addressed in order to determine whether there was a significant problem that required a substantial change in existing practices.

- Could anthropogenic substances cause effects on the endocrine system of animals and man through the aquatic environment?

- If so what substances might be responsible for these effects?

- How do these substances enter the aquatic environment?

- To what extent are they found in different stages of the water cycle?

In view of the complexity of the endocrine system, in the first instance effort was concentrated on oestrogens and the reproductive system, particularly since this was where most data were already available and most progress had been made.

The programme was developed with a number of different project areas;

- A study on endocrine disrupting compounds (EDC) in wastewater treatment, particularly sludge and biosolids,
- The development of reliable and practical analytical methods that could be applied widely by members of GWRC,
- Development of an assessment of the state of the science with regard to EDCs in the water cycle and a list of priority substances for monitoring and further investigation.

The specific objectives of this third project area, which is the subject of this report, were:

- An inventory of available data of occurrence of EDC in the water cycle (compounds, concentration, matrix)
- A consensus list of target compounds which can be used in further monitoring studies and method development
- A review of present information and knowledge

This information would be used to identify research needs and priorities.

The lead organisation was WRC in South Africa, supported by KIWA in the Netherlands and TZW in Germany.

Two questionnaires were circulated to members, one on monitoring data for EDCs in different parts of the water cycle, including wastewater and the second on the use of suspected EDCs and the analytical methods available to detect EDCs in each of the GWRC member countries. Most data were obtained from the USA and Europe.

A priority list was drawn up from knowledge of those substances that showed EDC activity and for which there was credible evidence that they could be in the water cycle. To be classed as potential EDCs the substances should show activity in accepted *in vitro* tests and/or *in vivo* animal studies and could be natural or synthetic. In selecting priority substances the potency of the substance is also a consideration in developing appropriate detection limits for individual substances.

The data were discussed in detail at a workshop. Presentations on the state of EDC research were given for each member country, including an expansion of the results given in the questionnaires and a list of possible research needs. A final priority list of EDCs was developed and a preliminary list of knowledge gaps was compiled. Members added additional knowledge gaps which they deemed to be important. These knowledge gaps were clustered and prioritised by the participating members to develop a smaller number of research areas and a number of project proposals were developed.

The overall groupings were:
- Impact and risks of EDC towards public health and the environment
- Analytical methods and monitoring techniques
- Occurrence and fate of EDC in different part of the water cycle.

The logical hierarchy in questions to be asked and activities to be undertaken is:
- What are the risks and impact of the problem
- What is the role and contribution of wastewater and drinking water to exposure of aquatic life and humans (monitoring of occurrence and fate)
- If necessary, how can it be cured (i.e. treatment).

It was recognised that there are a number of research initiatives underway outside GWRC and the water industry and that it is very important to maintain a watching brief to incorporate the results of such initiatives into the knowledge base of the GWRC programme.

To address the priority needs eight project proposal were developed during the workshop.

In this respect a project proposal *Public Health Impacts – Literature Surveillance and Reporting* was devised to keep the GWRC membership informed about recent research finding regarding the possible public health impacts of EDC, particularly through drinking water.

To improve the scope and quality of the monitoring activities on the occurrence and fate of EDCs, a project proposal *Evaluation and Testing of Analytical Methods* was developed.

Both projects will be of significant added value to the GWRC membership and are well suited to a cooperative effort.

1 Introduction

1.1 Background

The presence and effects of Endocrine Disrupting Compounds (EDCs) in the environment has become an important issue [Keith, 1997]. The endocrine system is a complex physiological process 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, particularly in higher animals. For example, estrogens in females and androgens in males play a key role in reproductive health. There are frequently cascades of hormones with complex feedback mechanisms to regulate the process.

The presence of low concentrations of some industrial chemicals and natural and synthetic hormones in water could affect or damage the functioning of the endocrine system. EDCs can mimic hormones or block hormonal activity such as anti-estrogens or anti-androgens. There is concern, and some evidence from aquatic populations that EDCs could give rise to changes that could lead to disruption of wild populations. The data that initiated the concern relate to fish, amphibians, reptiles and, to a lesser extent, birds exposed to anthropogenic chemicals through the aquatic environment. Significant changes were observed in the reproductive organs of alligators and turtles exposed to a mixture of persistent pesticides in a Florida Lake, while changes in the reproductive organs of male fish exposed to treated sewage effluent were also observed. Since some of the chemicals responsible may be discharged to waters used as a source of drinking water, concern. Has also been raised about EDCs in drinking water and their possible effect on man.

A range of substances have been shown to exhibit ED activity, usually in in vitro assays, but some in whole animals. These include:

- natural and synthetic hormones,
- phyto-estrogens,
- pesticides,
- organic solvents,
- pharmaceuticals (contraceptives and steroids),
- alkylphenols and alkylphenol-polyethoxylates,
- phthalates,
- organo-halogen compounds (like polychlorinated- and brominatedbiphenyls, diphenyl-ethers and dioxins)
- some heavy metals [Colborn, 1996; WWF, 1996; EPA, 1996].

In the case of natural and synthetic hormones, this refers to disruption of the endocrine system of other organisms such as fish affected by exogenous estrogens from other species, including man.

Many chemicals have not yet been investigated for ED activity. Screening for activity by means of bioassays or biomarkers is needed so that these chemicals can be assessed for potential risks. This may be particularly relevant for water since the total EDC activity measured in bioassays of water or water extracts, cannot always be

completely explained by the measured concentrations of natural EDC compounds in water [Lévi et al., 2002, Vethaak et al., 2002].

As indicated above, a number of circumstances have been reported where effects on wild populations have been attributed to natural and synthetic EDCs [Mukerjee et al., 2002]. These include reproductive problems in animal populations, such as alligators and fish-eating birds, feminisation of male birds, fish and alligators, the presence of the female specific egg yolk precursor protein, vitellogenin in male oviparous animals and ovotestis in male fish, sexual developmental defects known as intersex, and disturbance of sex ratio's in exposed populations [Vethaak et al., 2002]). The conclusion that anthropogenic chemicals can act as EDs and can impact on wild populations was also drawn in a recent IPCS review [IPCS 2002].

It has been suggested that certain EDCs may induce or promote breast cancer although there is considerable controversy in this area [Keith, 1997]. However, with regard to human health, there is, to date, no firm evidence for, or causal association demonstrated between low-level exposure to EDCs and adverse health outcomes [IPCS, 2002].

Humans and wildlife are exposed to chemicals via different pathways. Water appears to be an important component in the distribution of EDCs in the environment and is one of the pathways of exposure. This is particularly the case with aquatic organisms that can be permanently in contact with a waterborne ED.

The occurrence and activity of EDCs in water systems has been investigated in a number of studies. These studies show that a range of EDCs can be present in drinking water sources, particularly surface water (river), as well as in wastewater effluent [AWWA, 2002, Rhodes Trussell, 2002].

As a consequence of the concerns relating the above, the Board of the Global Water Research Coalition (GWRC) selected EDCs as the first priority issue for their collaborative research programme. As first step an inventory was made of the ongoing and planned EDC projects of the GWRC members. Twenty-three project were identified addressing a variety of aspects of EDC in the water cycle. The majority of the projects concerned analytical method development and the occurrence of EDC in the water cycle. The Board agreed on three joint activities: a project *EDC in WWT Sludge and Biosolids, a workshop Analytical Method Development and the project State-of-the-Science.*

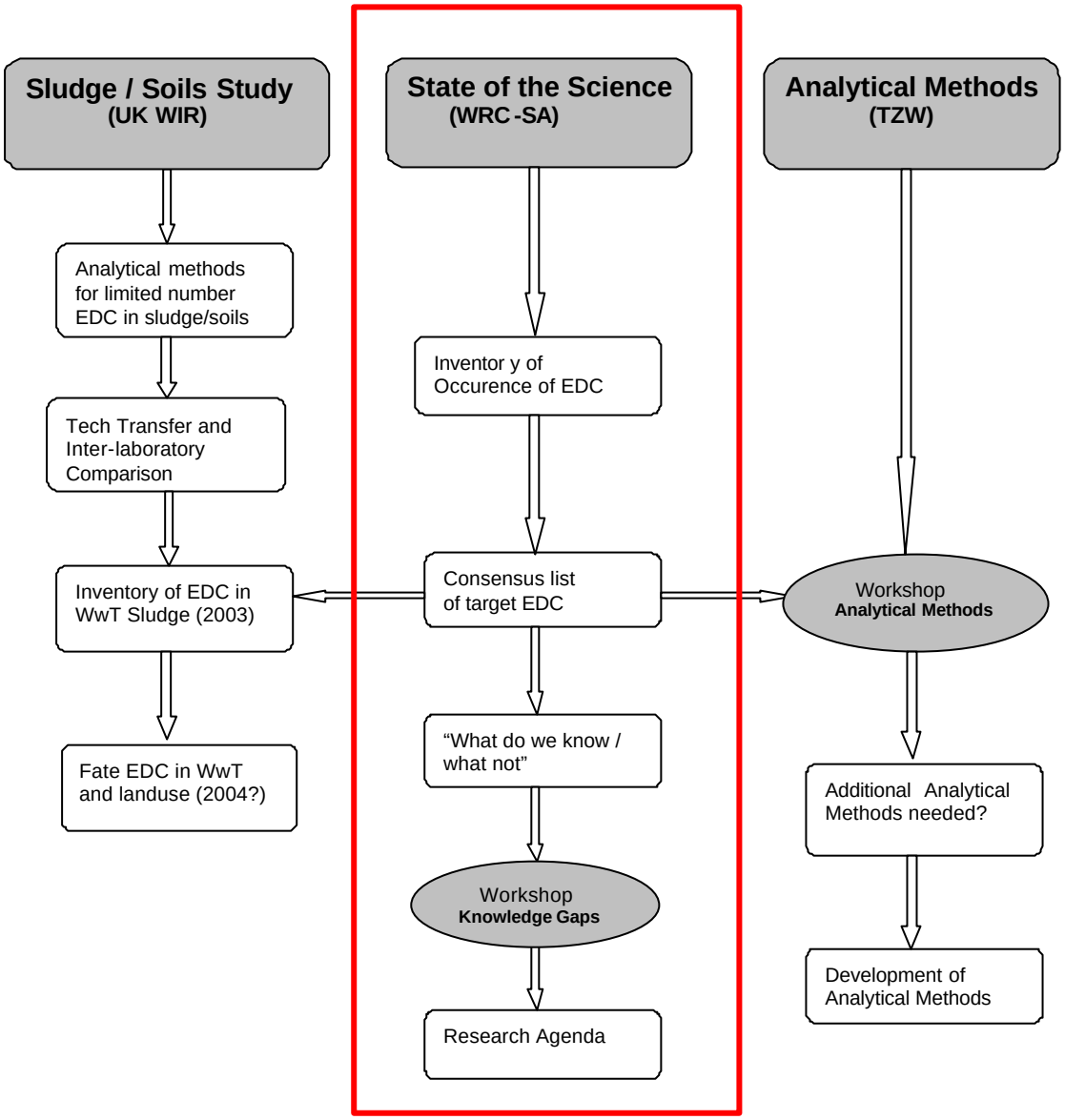

Figure 1: GWRC research activities in the field of EDC (GWRC, 2002)

As part of this latter, the Water Research Commission (SA) would develop in concert with the GWRC members a 'State-of-the-Science' report on EDCs in the water cycle with particular reference to the experience of member organisations and conduct a workshop to develop the research agenda. This, in turn, would be used to help identify the gaps in present knowledge with a view to formulating further research proposals to address these knowledge gaps. The elements of the different activities are shown in figure 1.

1.2 Aims and objectives of the study

The primary aim of the study was to explore the occurrence of EDCs in drinking water, wastewater and surface water with the following detailed objectives:

1. Compile an inventory of available data concerning the occurrence of EDCs in water systems that serve as a source of potable water (compounds, concentration, matrix) The most recent data and information to be made available by members of the GWRC;
2. Compile a list of target EDCs that should be monitored in further studies particularly regarding the removal efficiency of treatment processes;
3. Compile a review of information concerning endocrine disrupting activity as measured by different bioassays (see separate review prepared by KIWA);
4. Identify knowledge gaps and research needs and develop joint projects to address the needs.

This information would be used to identify additional information required to assess the risk of EDCs in the water cycle.

1.3 Approach

Two questionnaires were prepared and circulated to members in order to begin the process of gathering information. The first related to monitoring data for EDCs in different parts of the water cycle, including wastewater and sludge or biosolids available to or developed by member organisations. The second related to the use of suspected EDCs and the analytical methods available to detect EDCs in each of the GWRC member countries.

These data were compiled and used, with data from the literature, to develop a preliminary priority list of EDCs to inform future monitoring and research activities.

A workshop was finally convened with member organisations to discuss the available information and to expand on the responses in the questionnaires. They were also required to finalise the priority list and to develop an understanding of the information gaps in order to develop a potential research agenda.

1.4 Workshop Knowledge Gaps and Research Needs

1.4.1 Introduction

A workshop was held in Pretoria, South Africa from 6 – 9 October 2002 in order that the issue of EDCs in water could be discussed by the GWRC membership. It was hosted by the WRC and was attended by representatives of all of the seven member countries of GWRC. The process and overall outcome of the workshop are described and discussed in this report.

1.4.2 Scope of the workshop

- Exchange and consolidate present knowledge within the GWRC
- Identify knowledge gaps and research needs
- Define GWRC actions and activities in addition to ongoing studies
- Develop specific project proposals

1.4.3 Objectives of workshop

1. To complete the information regarding the report on occurrence of EDCs in water systems.
2. To consider the proposals on and obtain consensus on the EDC priority list to be utilized in further monitoring studies of EDCs in water systems.
3. To identify the research needs of the different members regarding EDCs in water systems.
4. To identify the knowledge gaps which need to be satisfied in order to meet the needs of the researchers and GWRC members.
5 To discuss potential research proposals for future research and actions within the GWRC.

1.4.4 Working Documents

The data collected from the questionnaires described above and the proposals for a priority list for future studies were circulated in advance of the workshop.

Two review presentations were also made at the workshop covering the biochemical and water technology aspects of the EDC issue. Each member was requested to prepare a presentation on the current state of EDC research in their country and to give a more detailed explanations of the data included in the returned questionnaires. The draft reports and the results of the questionnaires were presented and discussed in detail at the workshop. In addition a brief literature survey was performed and documented in *Endocrine Disrupting Compounds: an overview of sources and biological methods for measuring EDC* (GWRC 2003 a).

A preliminary list of knowledge gaps was compiled from this information and discussed, to which was added other knowledge gaps considered important to the members. These knowledge gaps were clustered and prioritized by the participating members.

2 Occurrence of EDCs in water systems

2.1 Introduction

This chapter is a compilation of the results of the inventory of the occurrence of EDCs in water systems. This was carried out by WRC, TZW and KIWA.
In order to make an assessment of the state of the science with regard to the occurrence of EDCs in various parts of the water cycle it is essential to establish the knowledge that is available. Much of this knowledge is not available through the published literature and is collected and developed by organisations for their own purposes. It is, therefore, particularly important to tap into this "grey" literature in order to develop a good understanding of the current state of scientific knowledge. This is particularly the case with subjects such as EDCs, since much of the data will be generated by water suppliers, wastewater undertakers and related organisations as part of their operations.

2.2 Approach of the inventory

In order to collect the data available within the GWRC membership on the occurrence of EDCs in water systems, two questionnaires were distributed to the members by e-mail, at the end of May 2002.

The first questionnaire requested monitoring/analytical data for EDCs in ground- and surface water, wastewater influent, effluent and sludge, as well as drinking water. The second questionnaire concerned the use of industrial chemicals considered to possess ED activity within the countries of member organisations and the analytical methods available to them for analysis of EDCs.

Nine GWRC members, representing seven countries, returned the completed questionnaires.

The results of the inventory were discussed and refined at the workshop.

2.3 Results the inventory

Members in Europe and the USA reported most of the data received. This was to be expected since these countries have ready access to the necessary infrastructure for sampling and analysis of water samples. In particular there is a requirement for advanced analytical capability to detect and quantify the very low concentrations necessary for many of the suspected EDCs.

A summary of the information regarding different groups of EDCs on the inventory is given below. The full information is documented in the report *Endocrine Disrupting Compounds: Occurrence of EDC in Water Systems (*GWRC 2003 b*).*

Natural and synthetic hormones
Five of the GWRC member countries reported data for hormones, namely Netherlands, France, Germany, Great Britain and USA. No positive results were reported in drinking water. The highest values for hormones were found in the influent of wastewater treatment plants.

Pesticides
France reported a small number of positive results for pesticides in drinking- and riverbank infiltrated water. These were mostly herbicides of the triazine family namely atrazine, simazine and terbuthylazine. The Netherlands, France, Germany and South Africa reported positive results for pesticides in surface water. These were predominantly persistent organochlorine compounds. In particular, South Africa reported some very high values for aldrin, dieldrin, DDE and lindane, although it is not clear what proportion were adsorbed to particulate matter.

Industrial chemicals

- Alkyl phenols and their ethoxylates.
Only The Netherlands reported values for octylphenol ethoxylates and nonylphenol ethoxylates in drinking water. The Netherlands and Germany reported values for nonylphenol in surface water. The Netherlands also reported values between 0.14 µg/l and 0.92 µg/l for octylphenol ethoxylates and 0.15-.2.6 µg/l for nonylphenol ethoxylates in surface water. Values of the same order were reported by the Netherlands and Germany in wastewater effluent.

- Phthalates:
Most of the data received has been generated in the Netherlands, with less data from Great Britain and Germany. Some data had also been contributed by South Africa. Significant values for phthalates have been detected in wastewater (influent and effluent) and surface water. In surface water the most commonly found phthalates are diethyl phthalate (DEP), dimethylpropylphthalate (DMPP), butylbenzylphthalate (BBP) and di(2-ethylhexyl)phthalate (DEHP).
The Netherlands and Great Britain also reported that DEP and DEHP were the dominant phthalates occurring in drinking water. These values were substantially lower than those reported for surface water

- Bisphenol A:
Only the Netherlands reported a value of <0.04-4.1µg/l in wastewater effluent.

- Polychlorinated Biphenyls (PCB) and Polynuclear Aromatic Hydrocarbons (PAH):
These are generally highly lipophilic compounds and adsorb readily to particulate matter in water. Only the Netherlands reported a value of <0.01-0.02µg/l for PCB in surface water. The Netherlands also reported values for PAH in surface water ranging from <0.01 to 0.1µg/l.

Toxic heavy metals
Arsenic, cadmium, lead, mercury were reported in the entire water cycle, with lower values in drinking water and higher values in surface and ground water. Very high values of toxic heavy metals in sewage sludge were reported by Australia, Netherlands and France.

2.4 Conclusions

The inventory of the GWRC data concerning the occurrence of EDCs in water systems clearly indicates that EDCs are found in surface water as well as in the influent and effluent from wastewater treatment. Concentrations of the different classes of EDCs vary from ng/l up to µg/l.

The limited data regarding drinking water supports the proposition that uptake of EDCs by humans from treated drinking water is relatively low in comparison to other sources such as food. However, the presence of EDCs in surface water is an indication that the use of untreated surface water, as drinking water, which is often the case in rural areas and informal settlements in urban areas of developing countries, is not without risk.

3 Priority list of EDC

3.1 Introduction

There are presently in excess of 4000 compounds that are reported to show endocrine disrupting properties, primarily in relation to estrogen and estrogenic effects, and this list is expanding as researchers investigate the properties of more compounds. The relative potency of these compounds varies depending on the type of methodology used to determine activity, for example E-screen, Yeast cell test or in vivo animal studies. In different species, differing levels of potency have also been observed. Aquatic fauna seem to be more susceptible to the effects of EDCs than other species, possibly because of the nature of exposure and the more labile nature of the reproductive system of many of these organisms.

The costs of monitoring the entire spectrum of potential EDCs in water and water-related media would be prohibitive and not all endocrine disrupting substances are likely to be present in aquatic systems. It was considered to be appropriate to compile a priority list of EDCs which would provide a basis for credible analytical determination of EDCs in water.

The groups of chemicals considered for inclusion in the priority list, were:
- hormones
- pesticides and herbicides
- industrial chemicals like alkyl phenols, phthalates and polychlorinated biphenyl compounds (PCBs), and
- heavy metals.

3.2 Priority list of EDC

A preliminary list of compounds was prepared on the basis of information received from the members of GWRC and submitted to the workshop of GWRC members for further refinement.
After elaboration all the information the participants agreed on a EDC Priority List to be used in future joint activities.

Table 3.1 reflects the EDC Priority List as agreed by the members. The present priority list is considered to be dynamic and compounds may be added or deleted as more information becomes available.

During the discussion a working list was compiled that included additional substances suggested by members, but for which not all the information about the criteria for inclusion was available at the time of the workshop. More information was subsequently gathered on these compounds and some were then added to the priority list. Those not included did not meet the criterion of being relevant to at least two of the members.

Table 3.1	**Priority list of EDCs**
Hormones 17ß-Estradiol Estriol Estrone 17a-Ethinylestradiol	**Heavy Metals:** Cadmium
Pesticides and herbicides DDT, DDE, DDD Dieldrin, Aldrin, Endrin, Isodrin a-Endosulphan, ß-Endosulphan, Endosulphan-sulphate Heptachlor, Heptachlor epoxide Lindane (?-BHC) Vinclozolin Parathion Atrazine Simazine Terbutylazine 2.4-D Metoxychlor Tributyltin Cyhexitin	**Industrial Chemicals** PCB (total) Glycol ethers *p*-Nonylphenol *p*-Octylphenol Phthalates: DEPH, DBP Bisphenol A

Furthermore a number of chemicals where listed as possible candidates:

Glyphosate	Amitrole
2,4-dichlorophenol	Kepone
DPCP (1,2-dibromo-3-chloropropane)	
Chlordecone	ß-BHC
Arsenic	Chrome VI

These substances are all reported to have shown endocrine disrupting properties, but it remains uncertain whether they meet all the criteria for inclusion.

More information about the EDC priority list is documented in the report *Endocrine Disrupting Compound: Priority List of EDCs (GWRC 2003 c)*. This report includes information about the selection criteria used, background information on the individual substances, the gathered information of relative potencies of the listed EDC, and the calculated and desired detection limits of analytical methods.

4 Knowledge gaps and research needs

4.1 Introduction

A workshop was held in Pretoria, South Africa from 6 – 9 October 2002 in order that the issue of EDCs in water could be discussed by the GWRC membership. It was hosted by the WRC and was attended by representatives of all of the seven member countries of GWRC.
Two review presentations were made at the workshop covering the biochemical and water technology aspects of the EDC issue. Each member was requested to prepare a presentation on the current state of EDC research in their country and to give a list of possible research needs.
A preliminary list of knowledge gaps was compiled from this information and discussed, to which was added other knowledge gaps considered important to the members. These knowledge gaps were clustered and prioritised by the participating members to develop a smaller number of research areas and a number of draft project proposals were developed. The outcome of the process is given below.

4.2 Feedback and presentations from members

4.2.1 AUSTRALIA *(Ian Falconer)*

Situation in Australia:

Extensive monitoring of contaminants in water supplies and river systems linked to sewage treatment has been in progress for decades. In general heavy metals, organics of industrial origin, pesticides and herbicides are monitored. No general monitoring of EDCs is in progress, however specific research projects on EDCs have been and are still being undertaken, in particular, the removal of pesticides and oestrogens during treatment is under investigation. Accumulation of pesticides in wild life has not been monitored, but heavy metals, pesticides and industrial organics have been monitored in birds, fish, mollusks, ocean mammals and human milk. Under the conditions in Australia, with coastal cities discharging mainly into the marine environment, agricultural chemicals are the main likely contaminants of river systems.

Report on occurrence list:

Only limited data was reported. Endosulfan, atrazine, simazine and chlorpyrifos have been detected, with the first two mentioned most commonly found.

Scientific gaps / future research needs:

Evaluation of the research needs on EDCs in Australia is currently underway.
The following subjects will be under investigation:
1. Rates of the breakdown of EDCs in the natural environment.
2. Ecological impacts on riverine fauna.
3. Evaluation of sewage treatments: implications for drinking water supply and reuse.

4.2.2 FRANCE (Maire-Laure Janex)

Situation in France :

Most of the research is carried out at the University of Pharmacy of Chatenay-Malabry, Paris. The research is mainly aimed at the quality of drinking water to the population of Paris. The Paris area is primarily supplied by drinking water abstracted directly or indirectly (bank filtration, artificial recharge) from the Seine River and its tributaries (Marne and Oise rivers). Drinking water treatment plants are located both upstream and downstream of Paris. The river downstream is significantly influenced by treated and untreated effluents which are the primary sources of EDCs in environmental waters.
In France sludge is extensively utilized in land application. New EC regulations are in preparation that will set limit values for various trace elements in sludge used for land application. Some of these compounds are EDCs. The Environmental French ministry asked AGHTM to launch a study in order to assess sludge quality and evaluate the impact of these proposed EEC regulations on future sludge management.

Glycol ethers which are still widely used in the world are of some concern in France. Methods need to be developed to measure these compounds at their toxicity reference concentrations.

Report on occurrence list:
Steroid hormones have been found at individual levels ranging from 0.03 to 20 ng/l at the outlet of 3 major wastewater treatment plants (WWTP). The results found by the in-vitro test are of the same order of magnitude than those found by chemical analysis (GC-MS). No positive results were reported to date using in vitro and in vivo assays in river waters/extracts collected upstream of the Paris area.

Scientific gaps/ future research needs:
1. The primary need is to have chemical and biological analytical methods to monitor EDCs in drinking water, wastewater and river water.
2. Methodology needs to be developed to analyse glycol ethers in environmental waters and conduct risk assessment on the exposure to these and other endocrine disrupting compounds.

4.2.3 UNITED KINGDOM (Gordon Wheale and John Churchley)

Situation in the UK:

The members from the UK are concerned with wastewater treatment and water supply. Most of the research is aimed at these issues as well as efforts to comply with the EU directives for drinking water.

Current research:
1. Current research is being conducted on method development in sewage sludge. The objective is to develop a method to determine the natural and synthetic oestrogens in sewage sludge. The target compounds are: Estrone, 17a-estradiol (E2), 17a-ethinyl; Estradiol (EE2); and Nonyl phenols.

2. Related UKWIR research includes a project on “Priority Substances”. This project arises from the EU Water Framework Directive and will subsume the provisions of Dangerous Substances Directive.

   ‘Priority Substances’ on the list include:
   Atrazine, Simazine
   Endosulfan
   Diuron, isoproturon,
   Di (2-ethylhexyl)phthalate (DEHP)
   Trichlorobenzene, napthalene
   Octylphenols, pentachlorophenol
   Chlorpyriphos, Trifluralin
   Lead and compounds

3. Current UKWIR Projects (2002-04): This programme includes a project called:
   A desk study to assess potential for Priority Substances appearing in sewage effluents, analysis of sources, a survey of occurrence, assessment of fate and the evaluation of treatment options.

4. Extensive surveys are undertaken regarding specific groups of EDC in sewage water treatment systems; large daily variation in concentration of EDC is observed. Removal efficiency of EDC on GAC and polymer adsorbents is studied.

Priority EDCs in UK:

Steroid Oestrogens (in order of potency):

- 17a-Ethinyl estradiol
- 17ß- Estradiol
- Estrone
- Estriol
- Alkyl phenols

Report on occurrence lists:
Valuable data were submitted on EDCs, especially concerning the levels in the influent and effluent in water treatment facilities. According to the data supplied EDCs are removed very successfully in these facilities and little or no residue remains in drinking water.

Scientific gaps/future research needs:

1. The primary needs are knowledge in connection with the fate and behaviour of EDCs in various treatment plants and facilities.
2. Cost effective analytical procedures for chemical analysis and bio-assays
3. Risk assessment especially on water going through wastewater treatment facilities.

4.2.4 THE NETHERLANDS K (Leo Puiker and Cora Uiterlinde)

Situation in the Netherlands:

The Netherlands has a comprehensive monitoring program in which occurrence and concentration of EDCs are determined in different parts of the water system. Research about removal of EDCs in drinking water treatment are ongoing.

Report on Occurrence of EDCs in the water system
A wide range of substances are monitored on a regular base. Only very low levels of EDCs are reported in drinking water. Higher values were reported in surface water and some even higher values in effluent.

The following EDCs were detected in surface water, process water and drinking water in the Netherlands: hormones, akylphenols and their ethoxilates, phthalates, pesticides, polycyclic aromatic hydrocarbons, PCBs, PBBs, PBDEs, organotin compounds and heavy metals.

Occurrence of hormones: Data was submitted for 20 natural and synthetic hormones. In drinking water all results were below the detection limit. Estrone, 17ß-Estradiol, 17a-Ethinylestradiol were detected in surface water. No data was available for ground water.
Occurence of alkylphenols and alkylphenol-ethoxilates: These substances were only detected at high concentrations in suspended matter (4-22µg/l).
Occurence of phthalates: DEP, DiBP, DBP, BBP and DEHP were detected in the rivers Rhine and Meuse. In process water and drinking water levels of 1-3 µg/l were reported.
Occurrence of pesticides: 25 pesticides are recorded as showing endocrine disrupting properties. The most frequently found pesticides in surface water are atrazine, simazine, carbendazim, metribuzin, lindane, metolachlor, parathion and malathion.
Some of these especially atrazine and simazine were found in ground water and drinking water. Other potential EDCs such as bisphenol A are frequently found in surface water (max. 22µg/l). Heavy metals were found at low levels in drinking water and surface water.

Scientific gaps / future research needs:
The research conducted on bio-assays includes the following:

1. Inventory of available bio-assays which includes an inventory of screening – techniques for measuring (potential) effects and the evaluation of the usefulness for drinking water and resources.

2. Inventory of in vitro bio-assays: Oestrogen-receptor binding test (ER calux): sensitivity: 50 % response (IC50) at 6-9 pM 17ß-estradiol.

3. Inventory of in vivo tests, which include wildlife studies and laboratory tests with fish.

4. Research on removal of EDCs. This will include a literature review on the removal of EDCs in different drinking water purification steps (the variation in efficiency),

the development of fast, cheap analytical methods for 11 priority EDCs and laboratory tests for a quick scan of these EDCs.

4.2.5 SOUTH AFRICA (Ansie Burger)

The situation in South Africa:

The first research projects in South Africa started in 1994. Most of the research is undertaken by universities and science councils in small projects. The focus of the research may be divided into the following sections:

1. The following species are being used in the search for biomarkers: the South African bullfrog, the catfish and other South African fish species.

2. Development of methodology to indicate oestrogenicity in aquatic systems mainly centers on verifying and applying tests such as the yeast cell test and the E-screen procedure developed in the USA and Europe as well as ELISA procedures to determine certain EDCs such as atrazine and PCBs in water.

3. The effect of DDT, is aimed at populations living in malaria affected areas and which are exposed to DDT as well as other agricultural pesticides. A previous study indicated that DDE is detectable in babies from mothers with relatively high concentrations of DDE in their blood. There seems to be a higher than normal incidence of interference in the reproductive organs of babies born in this area, but the reason for this is unknown.

4. The endocrine disrupting effect of p-nonyl phenol (PNP) on laboratory animals as well as the effect of DDT on birdlife. The effect of DDT on eggshell thickness was studied a few years ago.

5. The development of chemical methods to determine EDCs in water and sediment by means of GC-MS-TOF is a current research project. This forms part of an EDCs research programme undertaken by the WRC.

6. A research program on the occurrence of EDCs in South African water systems was initiated in 2002 and will run over 3 years to determine the extent of occurrence of EDCs in South African aquatic systems. It is undertaken under the auspices of the WRC and involves 5 universities, Technikons as well as the 3 research laboratories. The objectives of this project are:
    a. To undertake surveillance and to determine the occurrence and concentration of EDCs in South African dams and rivers,
    b. To determine the source of contamination as far as possible,
    c. To prepare an assessment of the risk to the urban and rural population,
    d. To establish procedures to manage and prevent the contamination

To date, South Africa does not have a monitoring program for EDCs in water systems, but the Department of Water Affairs and Forestry is planning to have a toxicology monitoring programme in place in 2008. In preparation for this programme the WRC has launched a program on EDCs in aquatic systems of South Africa and aims to get input from all different stakeholders to utilize their different but unique

skills in order to promote co-corporation between the Universities, Technikons and the research laboratories.

Report on occurrence

Most of the compounds proposed in the preliminary list of EDCs (Table 3.1) are still in use in this country. Very little, however, is known about the occurrence of these substances. This may be due to the following reasons:

1. The research projects were mainly done at Universities and the analytical data were produced by the students in non accredited laboratories. The credibility of these results could not be tested because detection limits were not mentioned, recovery tests were not done and analytical procedures were not well documented. These results were, therefore, not included in the questionnaires. The limited budgets for the students did not allow for analysis to be done at accredited laboratories.

2. Most of the data produced during the earlier years of EDCs research could not be used because the analytical procedures used in those projects did not meet the low detection limits needed for EDCs studies. The appropriate methods were only developed during the last few years. Should the earlier data be reported quite a number of false negatives will be included.

3. There are very few accredited laboratories doing EDCs analysis: The South African Bureau of Standards (SABS), Council for Scientific and Industrial Research (CSIR) and the Agricultural Research Council (ARC). Although the Water Boards have excellent laboratory facilities, these facilities are mainly utilized to determine microbiological contamination and "parameters" such as mineral content, nitrates and other substances. The three laboratories have confidentiality agreements with customers and are therefore not at liberty to publish the results without their consent. Most of the samples submitted to these laboratories are normally from problem sites in industrial areas, which do not really reflect the true status of water systems in the country. This was for instance the case in reporting very high values for dieldrin in certain samples.

4. Most of the research done was in small environmental projects that concentrated on river/dam/ground water. Practically no research was done on drinking water as defined in this GWRC project as water intended for human consumption. In South Africa a large portion of the population does not have access to purified water. These people drink water from sources such as rivers, streams and dams.

Future research needs/knowledge gaps in South Africa

The following needs were identified:

1. Extrapolation of the effect of EDCs from animal species to humans.
2. Effect of EDCs on human health and reproduction with special emphasis of DDT usage in malaria affected areas.
3. Effect of EDCs on population infected with AIDS and/or tuberculosis
4. Effect of EDCs on wildlife and environment.
5. Fate of EDCs in environment and purification systems and natural systems such as wetlands.
6. Management options for EDCs in the environment.
7. Purification of EDCs contaminated water for drinking purposes in rural areas.

4.2.6 THE USA (Djanette Khiari and Jami Montgomery)

Situation in the USA:

The two members attending the GWRC workshop are both from funding agencies. The current research is concerned with the discharge of EDC by wastewater (effluent and sludge), the removal of EDC in water reclamation systems, and with advanced treatment of water for drinking purposes and addressing public concern over the quality of drinking water. The following projects were highlighted:

1. Research Needs Workshop - EDCs and Pharmaceuticals in Drinking Water
2. Potential Endocrine Disruption in Receiving Water from Wastewater Discharges
3. The Use of Bioassays and Chemical measurements to Assess the Removal of EDC in Water Reclamation Systems
4. Endocrine Disruptors in Sewage Sludge
5. Assessment of Source Waters & Drinking Waters for Oestrogenic EDCs
6. Evaluation of Conventional and Advanced Treatment Processes to Remove EDCs & PhACs
7. Strategies for identifying emerging drinking water contaminants
8. Communication to address public concerns
9. Water quality improvements during aquifer storage & recovery

Report on occurrence:
The most frequently detected compounds in the US Geological Survey (USGS) study on organic wastewater contaminants in US streams (199-2000) were triclosan (anti-microbial) and nonylphenol (detergent); other contaminants measured were steroidal hormones and their metabolites, and insecticides and plasticizers.
Limited data on drinking water was received from the USA. This was due to the fact that data is regarded as confidential.

Scientific gaps/future research needs:

1. Research on cost effective analytical procedures including research on reliable bio-assays and identification of ED surrogates for monitoring purposes;
2. Occurrence data of EDCs in source waters and sediments including the temporal and spatial variability;
3. Risk assessment of EDCs in wastewater, water reuse and drinking water;
4. Innovative treatment techniques for controlling EDCs wastewater and drinking water;
5. Research on public health issues;
6. Research on ways to communicate EDCs contamination to the public and address public concerns.

4.2.7 GERMANY TZW (Frank Sacher)

The situation in Germany:

EDCs are officially identified as a possible environmental problem, but no official monitoring program is yet in place. It is recognized that EDCs may occur in wastewaters and surface water and that it may have effects on animals. EDCs are, however not officially discussed in relation to drinking water.

In 1996 the “Report by the German Environmental Agency (UBA) on the relevancy of synthetic EDCs in surface waters” was published. This was a literature survey on

- Methods for testing of endocrine effects, and
- the occurrence of EDCs in German waters
- a list of synthetic EDCs were identified (more than 200)

The outcome of this report:

- A list of 200 synthetic EDCs with short summaries on their use, sources and environmental fate (where available)
- The most relevant synthetic EDCs were identified as bisphenol A, nonylphenol and octylphenol , and tributyltin (TBT)

It was also felt that bio-testing for the effects of EDCs is not very reliable because different tests give different outcomes. The need exists for standardization of test procedures as well as information on the effects of exposure. Only limited occurrence data is available and some of this only from research projects.

Report on occurrence:

Waste water and surface water:

No official data is available. The data from research projects are sometimes not reliable. Pesticides, alkylphenols and steroidal hormones were detected. It was not certain whether the limits of detection were low enough. Most of the data given on surface water was reported on the aqueous phase and results on the suspended matter and sediment is not included.

Drinking water:

German water suppliers do not regard EDCs as a problem in drinking water and very few analyses are done because of the expense and difficulty. No bio-assays are conducted in drinking water. The data are also kept confidential.

Sewage sludge:

Officially no analysis is done on sewage sludge, but some research is conducted. Sometimes a combination of bio-assays and chemical analysis is used in these projects. There is ongoing discussion on the agricultural use of sewage sludge and research on EDCs in sludge is mainly funded by groups supporting a ban on agricultural uses.

Future research / scientific knowledge gaps

The following needs were identified:

1. Scientific methods for the assessment of EDCs in the water cycle
2. Development and validation of analytical methods for EDCs in different matrices
3. Links between bio-assays and chemical tests
4. Sources of EDCs
5. Studies on the fate of EDCs in water treatment plants (WWTP), Aquatic environment and during drinking water preparation
6. Knowledge on metabolites and conjugates

4.3 Identification of knowledge gaps and research needs

The knowledge gaps and research needs of the different countries (members) can be categorized in three sections:

- The need of reliable analytical methods for the assessment of EDC in water.
- The need to understand the fate of EDCs in water treatment facilities.
- The need to know the impact of and risk of EDCs to human health and environment.

In order to meet these needs 27 knowledge gaps and research needs were identified (Table 4.1). Some of these needs and knowledge gaps were clustered together because they seem to associated with the same area of research. The needs and gaps were prioritized, in order of importance to the members, as follows. More detailed information is given in Annex 1.

Table 4.1 Knowledge gaps & needs identified	
Analytical methods based on affordability	9
Bio assays	7
Public Health Effects: Low dose effects Bio markers Risk assessment tools Epidemiological studies	7
Fate of EDCs in waste water treatment plant	7
Environmental impact	6
Occurrence in the urban water cycle Sources of EDCs Agricultural chemicals in the environment	6
Fate in drinking water Metabolites and conjugates Removal technologies	6
Fate in surface water	6
Relative potency of EDCs	5
EDC in materials in drinking water distribution systems	4
Links between bio-assays and chemical analysis	2
Fate in sewage sludge and reclaimed water	2
Occurrence of EDCs in ground water	2
Effect of mixtures of EDCs and /or other chemicals on potency	1
Public perception on risk of EDCs	1
Regulatory strategies	1

For these needs and clusters as prioritized by the participating members, projects were developed around them. The most prominent proved to be a need for quick, reliable and cost effective analytical methods, both chemical and bio-assays.

Eight project proposals were developed to address the priority gaps and needs (the brief descriptions of the proposals are attached):

1. Public Health Impacts - Continuing Literature Surveillance and Reporting
2. Ecological Impact of selected EDCs on Aquatic Organism
3. Workshop on methodologies for chemical and biological analysis of EDC in water systems
4. Evaluation and testing of chemical and biological analytical methods for EDC in the water system
5. Sources of EDCs in the water cycle
6. Occurrence and Fate of EDCs in surface water
7. Fate and behaviour of EDCs in Waste Water Treatment (including sludge)
8. Fate and behaviour of EDCs in Drinking Water Treatment

The projects vary widely in scope, duration and costs. Some of the projects could directly be undertaken as specific GWRC activities, for several others is needed to clearly define the added value of the GWRC action in relations to the rapidly expanding portfolio of EDC research activities all over the world.

Of the four projects that address the needs with the highest priority (1, 3, 4 and 7) the workshop on Analytical Methods (3) is already agreed on and the project Fate and Behaviour of EDCs in WWT (7) is partly ongoing and the objectives as defined in this proposal can be consider the next phase of the ongoing WWT activities.

In addition to these activities, the project Public Health Impacts (1) could be considered as a joint GWRC activity; the further development and start the project Evaluation and Testing of Analytical Methods (4) is a logical step as a follow up of the workshop Analytical Methods .
The other four projects could be further elaborated with respect to the final scope, costs and (internal and external) funding possibilities, together with the members that have indicated to support the item. It is most likely that different subsets of members will be formed to develop and execute these possible joint actions.

5 Conclusions and Possible Future Research

5.1 Summary of conclusions

The inventory of the GWRC data on the occurrence of EDCs in water systems clearly demonstrates that EDCs can be found in surface water and in the influent and effluent of wastewater treatment plants. Concentrations of the different EDCs vary from ng/l up to µg/l.

The limited data regarding drinking water leads to the conclusion that the intake of EDCs from treated drinking water by humans is generally low, especially when compared to other sources such as food. There is evidence that many endocrine disrupters are removed by drinking water treatment, especially advanced treatment. However, the presence of EDCs in surface water is a clear indication that its use as drinking water without treatment, which is frequently the case in rural areas and informal settlements in urban areas of developing countries, is not without some risk.

The detection limits of analytical methods reported by the various countries vary significantly. There is a clear need for standard methods and detection limits for the various compounds.

There remain uncertainties regarding the concentrations of interest for many EDCs and , therefore, appropriate analytical detection limits.

The data reported was limited and although it indicated the presence of EDCs in aquatic systems it is considered to be inadequate for conducting risk assessments at this time.

Future research and monitoring activities should take account of the priority list of 34 substances (table 3.1), although this list will require to be modified in the light of new data.

5.2 Knowledge gaps and possible future research

The knowledge gaps and needs, and the priorities developed by the participating members are given in the table 4.1 and annex 1. Overall they can be grouped into three logical categories:

- Impact and risks of EDC towards public health and the environment
- Analytical methods and monitoring techniques
- Occurrence and fate of EDC in different parts of the water cycle.

There is also a logical hierarchy in questions to be asked and activities to be undertaken:

- What are the risks and impact of the problem
- What is the role and contribution of wastewater and drinking water to the problem (monitoring of occurrence and fate)
- If necessary, how can it be cured (i.e. treatment).

Eight project proposals are developed to address the priority gaps and needs (the brief descriptions of the proposals are attached):

1. Public Health Impacts - Continuing Literature Surveillance and Reporting
2. Ecological Impact of selected EDCs on Aquatic Organisms
3. Workshop on methodologies for chemical and biological analysis of EDC in water systems
4. Evaluation and testing of chemical and biological analytical methods for EDC in the water system
5. Sources of EDCs in the water cycle
6. Occurrence and Fate of EDCs in surface water
7. Fate and behaviour of EDCs in Waste Water Treatment (including sludge)
8. Fate and behaviour of EDCs in Drinking Water Treatment

It was recognised that there are a number of research initiatives underway outside GWRC and the water industry and that it is very important to maintain a watching brief to incorporate the results of such initiatives into the knowledge base of the GWRC programme.

In this respect a project proposal *Public Health Impacts – Literature Surveillance and Reporting* was devised to keep the GWRC membership informed about recent research finding regarding the possible public health impacts of EDC, particularly through drinking water.

To improve the scope and quality of the monitoring activities on the occurrence and fate of EDCs, a project proposal *Evaluation and Testing of Analytical Methods* was developed.

Both projects will be of significant added value to the GWRC membership and are well suited to a cooperative effort.

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Annex A Knowledge gaps and research needs (member priorities)

KNOWLEDGE GAPS AND NEEDS	AWWARF	WERF	UKWIR	Ondeo	KIWA	STOWA	TZW	WRC	CRC-WQT	total
Environmental impacts	x	x			x	x		x	x	**6**
Relative potency of EDC	x		x	x	x	x				**5**
Effects of mixtures of EDC and/or other compounds	x									**1**
Public health impact (water and sludge)		x	x	x		x	x	x	x	**7**
- Low-dose effects										
- Bio markers										
- Risk assessment tools										
- Epidemiological studies										
Public perception	x									**1**
Regulatory strategies				x						**1**
Analytical methods (affordable techniques, set criteria)	x	x	x	x	x	x	x	x	x	**9**
Bio assays	x	x		x	x	x		x		**6**
Links between bio tests and chemical analysis	x		x				x			**3**
Occurrence in the urban water cycle		x			x	x	x	x	x	**6**
- Sources of EDC										
- Agricultural chemicals in the environment										
Fate in Drinking water treatment			x	x	x		x	x	x	**6**
- Metabolites/Conjugates										
- Removal technologies										
Fate in sludge/reclaimed water used in agriculture		x	x							**2**
EDC in ground water							x		x	**2**
Fate in surface waters			x		x	x	x	x	x	**6**
EDC in chemicals or material in contact with dw	x	x		x			x			**4**
Fate in WWTP		x	x	x	x	x		x	x	**7**
- Metabolites/Conjugates										
- Removal technologies										
- Reclaimed water										

Annex B Project proposals following the 2002 GWRC workshop on EDCs

1. Project Title:	Public Health Impacts – Continuing Literature Surveillance and Reporting				
Name of Proposer & Affiliation:	Ian Falconor (CRC WQT) & Jami Montgomery (WERF)				
Collaborators:	Interested GWRC members				
	2002/03	**2003/04**	**2004/05**	**Beyond**	**Total**
Estimated Total Cost of Research x1000 €		50	20	2K/year	Depends on the length of the project.

Background:	**Justification:** The public health impacts of EDCs in the water cycle includes a number of the "knowledge gaps" identified in the EDC Workshop: **Low Dose Effects** – The context is the exposure for an extended period of time either continuously or intermittently. **Biomarkers** – A biological indicator of exposure eg., Enzyme inhibition, DNA Adducts, or Immune Suppression. **Risk Assessment –** Defining the appropriate adverse affects and appropriate tools for risk assessment for EDC's. Effects include behavioural, reproductive and neurological impacts. Tools include cancer risk assessment models and chemical safety assessment models.
Issue of concern:	It is considered that the GWRC and its members are not in a position to undertake research directly in these areas as a coalition. There may be some elements carried out by individual members as local circumstances dictate. However there is a critical need for continually updated information on the public health impacts in the environment as relates to the water and wastewater industry.
Consequences if work not carried out:	The water and wastewater industry needs to be kept informed on emerging public health issues of concern with regard to endocrine disrupting chemicals in order to respond proactively.
Collaboration, with whom, and why	
Benefits to be achieved:	
- Political	Will serve as an alert to potential future regulation and inform risk communication processes.
- Economic	This project describes a cost effective manner for the GWRC to remain abreast of latest research outcomes.
- Technical	The critical analysis of the literature provided in a practical format and enable ongoing identification of research gaps and priority issues.

Aiming to achieve: Specific questions answered:	**Objectives:** 1. Comprehensive review of the science, commencing from the recently completed WHO IPCS Global Assessment and other sources. 2. On an on-going basis provide a critical update to this initial review
Tasks set for contractor: Deliverables: Outputs: Completion date to maximise benefits:	**Description:** The data from investigations being carried out either by coalition members or other research agencies needs to be critically evaluated and presented to GWRC members in usable format. The evaluation of research material needs to include implications and relevance to the public health impacts related to: source water protection, drinking water and wastewater treatment, biosolids and water reuse. The contractor would start with the recently released WHO report *Global Assessment of the State-of- the-Science of Endocrine Disruptors.* A key project deliverable will be an ongoing web-based reporting system.
Target audience for the output? Which groups should receive any reports resulting from this work? Should the output be submitted for independent peer review to add authority to the work?	**Technology Transfer:** Water and Wastewater Utilities All collaborating organizations for distribution to their membership. There should be an advisory committee to oversee the contractor and provide technical guidance as needed.

2. Project Title:	**Ecological Impact of Selected EDCs on Aquatic Organisms**				
Name of Proposer & Affiliation:	Jami Montgomery (WERF)				
Collaborators:	Interested GWRC members				
	2002/03	**2003/04**	**2004/06**	**Beyond**	**Total**
Estimated Total Cost of Research x1000 €		100 –150	350 - 400		600 over 2-3 years

	Justification:
Background:	There is a body of scientific literature that indicates evidence of endocrine disrupting effects in individual aquatic organisms downstream of wastewater treatment discharges and agricultural runoff. However, there is less clear evidence of real biological effects at the population and ecosystem level. The recently released WHO report (Global Assessment of the State-of- the-Science of Endocrine Disruptors*)* states "*there is little information on linkages between exposure to putative EDCs and health outcomes in both humans and wildlife*" and "*that given the dynamic nature of the endocrine system, future efforts in the study of EDCs need more focus on the timing, frequency, and duration of exposure to these chemicals*." While GWRC members are not likely to have the resources to undertake the types of large-scale studies needed to investigate adverse health effects in humans, they are in a position to undertake research into how EDCs may directly effect aquatic wildlife.
Issue of concern:	How are aquatic biological systems impacted by anthropogenic sources of endocrine disrupting compounds (ie. wastewater treatment plant discharge, agricultural runoff, stormwater, potential runoff from land application of treated wastewater or sludge, etc)? Does the presence of biomarkers of EDC exposure correlate with any adverse health effects in aquatic organisms?
Consequences if work not carried out:	Utilities will continue to face questions and concerns from the public as to what are the actual biological effects of environmental exposure to these endocrine disrupting compounds.
Collaboration, with whom, and why	This project should be of interest to the USEPA as well.
Benefits to be achieved:	
- Political	This will help answer public concerns about the effect of anthropogenic inputs of EDCs on the natural environment.
- Economic	Will provide information to the water and wastewater industry on the level and seasonal timing of EDC removal that is necessary to prevent environmental damage. This is also relevant to the freshwater fishing and aquaculture industry.
- Technical	May help guide treatment plant technology and management practices for beneficial reuse of wastewater products.

Aiming to achieve: Specific questions answered:	**Objectives:** 1. Chemical characterization of the inputs into the watershed (wastewater treatment plant discharge, agricultural runoff, stormwater, potential runoff from land application of treated wastewater or sludge, etc). 2. Identify appropriate marker organisms from different trophic levels for the chosen watershed. 3. Do a population level field study focusing on linking biomarker of EDC exposure to any actual population level effects (ie. reproductive success and survival, immune function, neurobehavior, increased cancer rates, etc.)
Tasks set for contractor: Deliverables: Outputs: Completion date to maximise benefits:	**Description:** The first phase of this study will involve a chemical analysis of sources of selected EDCs and biomarkers of exposure in native species. Researchers should focus on a watershed that is significantly impacted by one or more of the above mentioned anthropogenic sources of EDCS. The second phase should be primarily a field-based study of aquatic ecology that should include seasonality of exposure, temporal variability in water quality parameters, flow changes, etc. Careful attention will need to be paid to the selection of an appropriate reference watershed for this study. The contractor will be expected to make practical recommendations for changes in appropriate best management practices if the results of this study warrant such action. These recommendations could include changes in beneficial reuse practices based on seasonality of health effects, additional treatment of inputs such as wastewater effluent, stormwater, or agricultural run-off, etc. A report that includes study results and suggested changes in best management practices. 2005/2006
Target audience for the output? Which groups should receive any reports resulting from this work? Should the output be submitted for independent peer review to add authority to the work?	**Technology Transfer:** Member organizations and scientific community. Member organizations. There needs to be an advisory committee to oversee the contractor and provide technical guidance as needed.

3. Project Title:	**Workshop on methodologies for EDC-specific chemical and biological analysis in water systems**				
Name of Proposer & Affiliation:	Frans Sacher (TZW)				
Collaborators:	AWWARF, WRC, WERF, UKWIR, Ondeo, KIWA, STOWA, CRC-WQT				
	2002/03	**2003/04**	**2004/05**	**Beyond**	**Total**
Estimated Total Cost of Research x1000 €		**50**			**50**

	Justification:
Background:	There are knowledge gaps on available analytical methods for analysing EDC in water systems and there is need to better correlate biological methods with chemical analytical methods
Issue of concern:	Availability of analytical methods for analysing EDC in water systems, evaluation of the methods with a sharp focus on sensitivity, selectivity, robustness, ease-of-use, automation, costs
Consequences if work not carried out:	No solid risk assessment effort can be undertaken without prior identification/selection of solid analytical methods. Credibility of risk assessment is at stake
Collaboration, with whom, and why	GWRC members (highest priority project identified during SA workshop)
Benefits to be achieved:	
- Political	To protect public health
- Economic	Comparison and evaluation of analytical methods with regard to costs (instrumentation and man power)
- Technical	Generation of reliable methodologies for EDC analysis as a base for future analytical and risk assessment data

	Objectives:
Aiming to achieve:	Identify the most appropriate state-of-science analytical methods for EDC in water systems and identify needs for further development
Specific questions answered:	Availability of chemical and biological analytical methods for EDC; evaluation of the methods with regard to sensitivity, selectivity, robustness, ease-of-use, automation, costs
	Description:
Tasks set for contractor:	Identify state-of-science analytical methods for EDC, prepare and evaluate a questionnaire, identify and invite experts in the field of EDC analysis, prepare a state-of-science report, organise a workshop
Deliverables:	Workshop report including recommendations for further evaluation and use of analytical methods
Outputs:	Reliable chemical and biological analytical methods and directives for further analytical research
Completion date to maximise benefits:	15.07.2003
	Technology Transfer:
Target audience for the output?	GWRC members and stakeholders
Which groups should receive any reports resulting from this work?	GWRC members
Should the output be submitted for independent peer review to add authority to the work?	No

4. Project Title:	**Evaluation and testing of chemical and biological analytical methods for EDC in the water system**				
Name of Proposer & Affiliation:	Djanette Khiari (AwwaRF)				
Collaborators:	GWRC members				
	2002/03	**2003/04**	**2004/05**	**Beyond**	**Total**
Estimated Total Cost of Research x1000 €		150	100		250

	Justification:
Background:	Methods selected during the workshop on analytical methods that need to be tested in the laboratory
Issue of concern:	Take into consideration effects of mixtures and matrix effects (source and drinking water, waste water, sludge)
Consequences if work not carried out:	Reliability and credibility of risk assessment is at stake,
Collaboration, with whom, and why	
Benefits to be achieved:	
- Political	
- Economic	
- Technical	Association (correlation) of presence of EDC and health effects.

	Objectives:
Aiming to achieve:	This project would be a follow-up of the analytical methods workshop. The objective would be confirm the feasibility of methods and to identify the potential for further method development. It will encompass both chemical methods and bioassays. Provide a tool to be used to determine the effect of EDC on human health.
Specific questions answered:	Determine specificity, selectivity, limits of detection and applicability of methods in different water matrices
Tasks set for contractor:	Testing on selected methods and development of additional methods
Deliverables:	Tested and possibly standard methods
Outputs:	Tested and possibly standard methods
Completion date to maximise benefits:	2003
Target audience for the output?	GWRC, regulatory agencies, utilities
Which groups should receive any reports resulting from this work?	
Should the output be submitted for independent peer review to add authority to the work?	Yes

5. Project Title:	Occurrence and Sources of EDCs in the Water Cycle				
Name of Proposer & Affiliation:	Leo Puijker (KIWA)				
Collaborators:	WERF, KIWA, STOWA, TZW, WRC, CRC/WQT				
	2002/03	**2003/04**	**2004/05**	**Beyond**	**Total**
Estimated Total Cost of Research x1000 €		100	100		200

	Justification:
Background:	The presence of EDCs in surface waters has been linked to adverse impacts on wildlife in different situations around the world. Those observations have been the subject of alarmist reports in the media and have raised concerns about the safety of certain surface waters for use as sources of drinking water. However, knowledge about the occurrence, sources and control options of EDCs in surface waters is limited. More information is needed to facilitate the management of the water cycle so as to reduce the risks to environmental and public health.
Issue of concern:	Public health concerns and the adverse impact on the environment.
Consequences if work not carried out:	Increasing public concerns and risk of adverse environmental effects.
Collaboration, with whom, and why	Possibility of collaboration with Government Agencies to share costs.
Benefits to be achieved:	
- Political	Better management of all parts of the water cycle.
- Economic	Identification of source control methods in order to avoid costly end-of pipe solutions.
- Technical	Identification of critical control points to enable the most cost effective control opportunities.

	Objectives:
Aiming to achieve:	Cost-effective control of EDCs in the environment.
Specific questions answered:	Where are the critical control points for EDCs in the water cycle?
	Description:
Tasks set for contractor:	The project will provide information on: • Manufacture and use of EDCs • Major point source emissions • Agricultural inputs, including phytoestrogens • Metabolic inputs • Urban runoff • Other diffuse sources • Opportunities for control at source
Deliverables and Outputs	A technical report (or reports, depending on the phasing of the research) and workshop.
Completion date to maximise benefits:	2006
	Technology Transfer:
Target audience for the output?	Water boards, pharmaceutical industry, Agricultural industry, Urban planners,
Which groups should receive any reports resulting from this work?	GWRC
Should the output be submitted for independent peer review to add authority to the work?	By GWRC members

6. Project Title:	**Occurrence and Fate of EDCs in Surface Waters**				
Name of Proposer & Affiliation:	Leo Puijker (KIWA)				
Collaborators:	UKWIR, KIWA, STOWA, TZW, WRC, CRC/WQT				
	2002/03	**2003/04**	**2004/05**	**Beyond**	**Total**
Estimated Total Cost of Research x1000 €		200	200		400

	Justification:
Background:	The presence of EDCs in surface waters has been linked to observations of physiological changes in fish species in some rivers containing high concentrations of sewage effluents. Those observations have been the subject of alarmist reports in the media and have raised concerns about the safety of certain surface waters for use as sources of drinking water. However, knowledge about the occurrence, sources and fate of EDCs in surface waters is limited, and recently completed research (COMPREHEND) found wide and unexplained variations in samples taken in a study of rivers in the EU. Greater knowledge about the occurrence and fate of EDCs in surface waters should facilitate the management of the water cycle to reduce the risk to environmental and public health.
Issue of concern:	The quality of surface water systems, with respect to the suitability of the waters for use in different functions, (ecology, drinking water resources, recreational etc).
Consequences if work not carried out:	Increasing public concerns and risk of adverse environmental effects.
Collaboration, with whom, and why	Possibility of collaboration with Government Agencies to share costs.
Benefits to be achieved:	
- Political	Reduced public concern about the quality and safety of surface waters.
- Economic	Reduced costs due to better management of the water cycle.
- Technical	Improved knowledge and ability to manage the water cycle.

	Objectives:
Aiming to achieve:	Surface waters of good quality that meet the needs of down-stream users and the environment.
Specific questions answered:	• How widespread is the occurrence of EDCs in surface waters, and what concentrations are typical? • Are there any effects to be expected (health, ecosystems) • How persistent are they? • How do natural processes reduce the EDC loads in surface waters?
	Description:
Tasks set for contractor:	It is expected that a literature survey coupled with tests at bench, pilot and full scale will be required to provide information on: • Concentrations of EDCs in surface waters including 'new' chemicals known or suspected as EDC • Measured effects of 'unknown EDCs' with bioassays (in vitro– and in vivo-tests), related to measured concentrations • Partitioning of EDCs between liquid and solid phases • Persistence of EDCs • Degradation mechanisms and kinetics e.g. through UV oxidation? Biological processes? (also in project fate EDCs in treatment) • Occurrence and fate of metabolites • Sources of emission of EDCs to surface water • A predictive tool to extrapolate results for use on a range of different waters
Deliverables and Outputs:	A technical report (or reports, depending on the phasing of the research) and workshop.
Completion date to maximise benefits:	2006
	Technology Transfer:
Target audience for the output?	Water Boards, regulators and the water industry.
Which groups should receive any reports resulting from this work?	GWRC members
Should the output be submitted for independent peer review to add authority to the work?	By GWRC members

7. Project Title:	Fate and Behaviour of EDCs in Waste Water Treatment, (including sludge treatment)				
Name of Proposer & Affiliation:	Gordon Wheale (UKWIR)				
Collaborators:	WERF, UKWIR, Ondeo, KIWA, STOWA, WRC, CRCWQT				
	2002/03	**2003/04**	**2004/05**	**Beyond**	**Total**
Estimated Total Cost of Research x1000 €		250	250		500

	Justification:
Background:	Wastewater is the major source of priority EDCs in surface waters and WWTW effluents have been linked to subtle physiological changes in fish species found in rivers below the points of effluent discharge. In some countries, Regulatory Agencies are considering how to implement controls on wastewater effluents in order to protect the health of fish in the receiving waters. Irrespective of controls, the media raises the concern of the public about the potential impact of EDCs in wastewater effluents, sludge's and surface waters.
Issues of concern:	• There is increasing pressure for controls on the discharge of endocrine disrupting substances to the environment. The water industry has little information on the technologies it might adopt to ensure that effluents comply with any applied controls. • In many countries, sewage sludge is recycled to agricultural land, and operators are concerned to protect that route, since incineration and landfill are expensive and sometimes controversial options. • The perception and concerns of the public about the quality of receiving surface waters for water supply.
Consequences if work not carried out:	• Non-compliance with possible future regulations. • Loss of an important sludge disposal route. • Inability to demonstrate to the public that WWTW provide adequate protection of surface water quality and health.
Collaboration, with whom, and why	
Benefits to be achieved:	
- Political	Addresses public concerns over the quality of surface waters and the safety of sludge disposal to agriculture.
- Economic	Provides information to allow the selection of cost-effective technologies to meet future standards and to protect sludge disposal routes.
- Technical	Understanding of wastewater treatment systems and the ability to optimise systems for most cost effective treatment.

	Objectives:
Aiming to achieve:	• Improvement of surface water quality by minimising the discharge of EDCs from wastewater effluents. • Protection of animal and public health by securing safe sludge disposal processes.
Specific questions answered:	• How do we operate WWTP to remove EDCs efficiently? • Which systems are cost effective? • Are EDCs biodegraded in sludge treatment systems so that the risk of entry into the food chain is minimised?
	Description:
Tasks set for contractor:	It is expected that a literature survey coupled with tests at bench, pilot and full scale will be required to provide information on: • Removal efficiencies of different wastewater treatment processes, (including conventional sludge treatment processes). • The mechanisms and kinetics of treatment, (including conjugate reactions) • Process optimisation opportunities • The effectiveness of emerging treatment systems, e.g. MBR • The effectiveness of targeted advanced treatment systems, e.g. ozone/GAC (?? Strong competition with organic matter) • Mass balances and partitioning • Efficacy of processes for reclaiming water for downstream uses • Produce models to predict removals and optimise treatment. Parts of the objectives are included in the project on sludges that has already begun.
Deliverables and Outputs:	A Report –or a series of reports, depending on the phasing of tasks.
Completion date to maximise benefits:	2006
	Technology Transfer:
Target audience for the output?	Water Industry and regulators
Which groups should receive any reports resulting from this work?	GWRC members
Should the output be submitted for independent peer review to add authority to the work?	By GWRC members

8. Project Title:	Fate and Behaviour of EDCs in Drinking Water Treatment				
Name of Proposer & Affiliation:	Gordon Wheale (UKWIR), Guus IJpelaar (Kiwa)				
Collaborators:	UKWIR, Ondeo, KIWA, TZW, WRC, CRC/WQT				
	2002/03	**2003/04**	**2004/05**	**Beyond**	**Total**
Estimated Total Cost of Research ($k)		*400*	*600*		*1,000*

	Justification:
Background:	The presence of EDCs in source waters raises concerns about the safety of the water as a source of drinking water. Information is needed about the removal of EDCs in order to allay public health concerns. Research is currently performed on the removal and degradation of selected EDCs using bench-scale test methods. The obtained results will give an indication of the capacity of conventional and advanced treatment processes for the removal of EDCs under drinking water process conditions. In order to ensure that the treatment processes as the Waterworks currently applies them, are a barrier against EDCs with respect to public health and concern, a translation of the bench-scale results to practical operation is needed.
Issue of concern:	Public Health
Consequences if work not carried out:	Increasing public concern
Collaboration, with whom, and why	To be established in consultation with the other partners within GWRC. Interested to collaborate in this project are: • University of North Carolina, USA (Detlef Knappe): expertise on adsorptive removal, lab tests available • University of New Hampshire, USA (Jim Malley): expertise on UV and UV- and ozone-related oxidation processes, lab tests available • NV PWN Water Supply Company North Holland, Netherlands: UV(/H_2O_2)/GAC pilot plant available • Waterworks of Amsterdam, Netherlands: ozone/GAC pilot plant available • NF/RO Plant • American Water Works
Benefits to be achieved:	
- Political	Addressing public concerns about drinking water quality
- Economic	Provides information to allow the selection of cost-effective technologies.
- Technical	Provides information to allow the selection and optimised the operation of treatment systems.

	Objectives:
Aiming to achieve:	Drinking water that is free of EDCs, meets standards and the needs of customers.
Specific questions answered:	Do treatment processes (and process conditions) as currently applied by WTPs form an adequate barrier against EDCs? If not, at what conditions should the WTP be operated? How do we operate WTPs to remove EDCs efficiently? And which systems are cost effective?
	Description:
Tasks set for contractor:	It is expected that a literature survey coupled with tests at bench, pilot and full scale will be required to provide information on: o Removal efficiencies of different water treatment processes o Concentration of EDCs in drinking waters, if any o The mechanics and kinetics of treatment o Options for optimising treatment o By-product formation *(degradation products?)* and minimization o The feasibility of using QSAR techniques to support the research work.
Input: *Research will be based on the removal/degradation of EDCs by both applied and new treatment processes. In a first stage an expanded bench-scale research may be conducted. A second stage could be a translation to pilot-plant scale and/or full scale. Full-scale installations will only be used in this research when EDCs are present in the water and removal can be measured.* *The treatment processes in both stages will be UV, ozone, and activated carbon related processes as well as nanofiltration/reverse osmosis, thus covering most surface water treatment processes. Research on activated carbon will also give an indication whether this process is a barrier against EDCs in ground water. The research parameters may be: the kind of treatment process, selected EDCs at different concentrations, range of process conditions, water quality if treatment processes can be utilized at different locations.* *By-product formation under the applied conditions can be taken into account, e.g. bromate formation using ozone. The project may be expanded by: measuring degradation products,and the efficiency of treatment processes on the endocrine disrupting effects of certain water types using bioassays*	
Deliverables and Outputs:	A Report –or a series of reports, depending on the phasing of tasks.
Completion date to maximise benefits:	2006
	Technology Transfer:
Target audience for the output?	Water Industry and Regulators, Drinking water customers
Which groups should receive any reports resulting from this work?	GWRC members
Should the output be submitted for independent peer review to add authority to the work?	By GWRC members