



Australian Government
Land & Water Australia

Targeting Endocrine Disruptors in Australia's Waterways

When the media reported the intriguing story of 'gender bending' chemicals causing fish in UK streams to develop male and female sex organs, research teams began to investigate the cause.

The gender benders, actually endocrine disrupting chemicals (EDCs), were mainly natural and man-made hormones excreted by humans, and some industrial chemicals. Even in trace amounts, the EDCs alter levels of hormones and specific proteins. This in turn causes intersex (both male and female reproductive glands), imposex (females with male sex glands), reduced sperm counts, deformed sperm, and reduced production of viable eggs.



The endocrine system uses hormones to send signals around the body to control blood pressure, stress responses, body temperature, reproductive processes and other functions. It is critical for the endocrine system to be working well to maintain good health. The contraceptive pill and insulin are examples of ways we can take advantage of being able to disrupt the endocrine system.

Clearly, effects on biological systems are definitely possible if endocrine signalling is disrupted. Whether these effects are widespread in the environment and whether changes in signalling actually lead to adverse effects are important questions to be addressed.

Studies at sewage treatment plants overseas indicate that even highly treated effluents are likely to contain enough natural and/or human-made hormones to cause impacts in fish unless diluted significantly when discharged from the plant into the waterways.

Developing a good understanding of the impact on Australian fish is critical at this point. This information will then inform the decisions made about improvements to treatment technology for removing these and other endocrine disruptors.

Levels of these disruptors in treated Australian effluent are similar to those detected in UK water treatment plants. Sound scientific data on EDCs and their effects on our waterways is lacking, but there are still important ramifications regarding planned national initiatives for water re-use and recycling for environmental flows and drinking water.

Questions arise, too, on the possible effects of EDCs on unique Australian native flora and fauna such as marsupials.

A number of Australian groups are intent on highlighting this issue as one requiring national attention and action. On 24 November 2007, Australian and international researchers, policy makers, regulators, water suppliers and research investors drafted the first national position paper on EDCs: *The 2007 Black Mountain Declaration on Endocrine Disrupting Chemicals in Australian Waters*. The paper focuses on environmental and human health implications and recommends future research objectives as well as attention to policy and public awareness.

Why Australia is involved in the EDC issue



EDCs are a matter of concern because

- they are definitely present in the Australian environment at levels shown to have detectable effects in the UK
- effects depend on timing of exposure as well as level of exposure, so the normal methods for predicting impacts need to be applied with care and potentially amended
- slow and subtle effects are often difficult to discern and may take time to manifest as adverse conditions
- they are mobile in water, are sometimes persistent, and concentrate in biosolids
- responsibility for their management is dispersed among local, state and federal governments and environmental authorities whose knowledge and resources may be limited.

The issue is likely to become more acute because

- increasing urbanisation of human populations result in more EDCs being released into the environment in each location
- new EDCs are being discovered, developed and added to the environment
- EDCs are present in sewage effluent (mainly steroid hormones), agriculture (mainly pesticides), and in dairies, feedlots and other livestock industries (mainly persistent organic pollutants and plasticisers)
- encouraging householders to reduce water use means these chemicals are not being diluted as much in the sewerage system, and therefore concentrations in discharges are likely to increase
- drought and other pressures to establish water marketing will result in more re-use of waste water
- tradeoffs between water quantity and quality will emerge in market-based resource systems
- climate change is likely to increase the importance of effluent flows for rivers and ecosystems
- new detection and treatment technologies will enhance monitoring and risk assessment processes, and increase awareness of the issue
- threats to human and ecosystem health are newsworthy (for example, a proposal to reuse wastewater in Queensland in 2004 failed to gain community support in the face of media fuelled public concerns overriding sound scientific data).

Government has a vested interest to commit because

- this issue falls within the government's national research priority of 'An Environmentally Sustainable Australia' and identification of water as a critical resource in ecosystem health
- increasing water reuse and demand (at a time when climate change policy papers are under the microscope)
- strategies to target EDC research in areas relevant to human health are being pursued vigorously in the United States (the US Government has provided US\$30–50 million) and Europe (governments have committed €145 million to fund research)
- Australia's Department of Environment, Water, Heritage and the Arts is uniquely positioned to address the EDC issue with a focus on Australia's unique flora and fauna
- new generation water quality guidelines should include EDCs
- the impact on economic resources, such as fisheries, could be significant
- human health issues in the reuse of potable water is an emotional topic for the public and needs to be underpinned by scientific data
- researchers have shown that concentrations of EDCs in treated sewage and wastewaters in Australia are comparable to those found in Europe, making it imperative that this issue be addressed at a national level
- media reports will stimulate community interest and concern and the implications of the presence of EDCs in the aquatic environment will need to be communicated to the public
- commercially viable solutions may benefit from partnerships of government, research and industry.

Why Australia should invest in EDC monitoring of native species



EDCs are a matter of concern because

- basic understanding of the biology of many native species is quite limited, which means it is difficult to predict likely effects of current environmental levels of EDCs
- to increase confidence in concluding whether or not observed responses are a result of exposure to EDCs, it is important to consider:
 - large sample sizes
 - seasonal changes (spawning)
 - life history
 - comparison of effects with reference populations of the same species
 - reproduction of effects under controlled laboratory conditions and
 - impacts arising from the inclusion of multiple species.
- beyond the imperative that wildlife should be protected, our native species serve as sentinels for effects produced by endocrine disruptors that may as yet be unobserved in humans.

There is insufficient data to confirm

- what levels of EDCs cause adverse effects in native fauna
- whether natural and synthetic hormones present in sewage effluents are affecting aquatic organisms
- whether feedlots and intense animal husbandry facilities can manage EDC release
- whether industry practices such as wool scouring are potential sources of EDC release
- what other modes of endocrine disruption need to be explored — for example, male sex hormone responses in waste water plants, thyroid disruption in native frogs, and endocrine changes in reptiles, amphibians and invertebrates
- how EDCs affect the reproductive biology of Australia's unique wildlife — for instance, marsupials could be susceptible to adverse hormonal effects during early development in the pouch when they cannot access their mother's protective detoxification systems
- the effects of exposure to mixtures of EDCs and other chemicals.

Summary



The unfolding EDC story



EDCs are a matter of concern because

In the early 1990s researchers identified the potential for some oestrogenic hormones to disrupt the endocrine communication system in a range of environments. This work led to the publication of a popular science book called *Our Stolen Future*.

In the United Kingdom, a study on fish from rivers receiving effluent from sewage treatment plants was started because fishermen noticed that the reproductive organs of some of the fish were abnormal. This study was one source of the gender bending stories covered by the popular press.

The scientists identified an industrial chemical as the cause in some locations; they expected to find traces of the active ingredient of the contraceptive pill but initially analytical procedures were not sensitive enough. As these analytical procedures improved, it was found that the main contributor to the intersex condition in most locations was the natural hormones that humans excrete every day. Vitellogenin (a protein used in egg production) was detected in affected male fish. The scientists used this biomarker to prioritise locations for research. The biomarker showed this exposure in fish was fairly widespread. Scientists went on to show a definite link between this intersex condition and reproductive success.

Oestrone (E1) levels found in UK effluents ranged up to 76 ng/L, and 17 β -oestradiol levels (E2) ranged up to 50 ng/L.

How were these results used in decision making?

This detailed scientific work over ten years resulted in the World Health Organisation, in its science assessment in 2002, to conclude that there is strong evidence of effects on fish downstream of sewage treatment plants and that these effects are likely to be caused by chemicals disrupting the endocrine system of the fish. Subsequently, scientists and water authority experts drafted the *Prague Declaration*. This was an important reference document for policy makers because it updated research progress and made constructive suggestions that might lead to better protection of human life.

The UK Environment Agency and the European Chemicals Bureau used the information from the UK study to draft concentrations of these chemicals that would protect aquatic life from adverse effects. They set draft guidelines for natural hormones like E1 and E2 at levels below 5 and 1 ng/L, respectively, whereas the active hormone in the contraceptive pill and hormone replacement therapy, 17 β -ethinyloestradiol (EE2), should not exceed 0.1 ng/L.

The levels of EDCs found in UK sewage treatment plant effluents are not diluted much when discharged to the environment — these effluents contribute up to 80 per cent of the flow in rivers. Significantly, EDC levels in many UK rivers are above the proposed water quality guidelines.

The UK Government has funded research for many years now. In the most recent round of funding, grants totalled £40 million over five years for a group of studies scheduled to finish in 2009. This funding was allocated partly for research clarifying the final pieces of the environmental risks puzzle, but more towards designing and testing treatment technologies. Once the results of technology trials and estimates of risk are available, decisions will be based on prioritising plants for upgrade in terms of the technology, cost effectiveness and reduction of risk.

What other countries found

Many countries have tested for oestrogenic hormones in sewage treatment effluents to gauge the level of risk to fish and other organisms.

In Canada, Denmark, France, Germany, Netherlands, Sweden, Spain, Switzerland and Italy scientists found E1 levels up to 100 ng/L and E2 levels up to 64 ng/L. In Japan and Taiwan the corresponding maximum figures were 180 ng/L and 40 ng/L.

In the United States, levels were somewhat lower. This was thought to be because of the much greater dilutions commonly found when sewage effluents are discharged from treatment plants. A recent field study in Boulder Creek, Colorado, looked at both hormone levels and impacts on fish reproduction. The sewage treatment plant discharging to this creek contributes less than 10 per cent of the flow in the creek during high flow conditions but up to 75 per cent of the flow during low flow. Researchers detected E1 levels at about 100 ng/L, E2 at about 2 ng/L, and EE2 up to 2 ng/L. Researchers found the biomarker, vitellogenin, in the fish and fish with the intersex condition, and reduced size of sex glands, skewed sex ratios and disrupted structures in gland cells. Even at these low hormone levels, significant effects were seen when compared with the fish upstream that were not exposed to the effluent. The lead researcher from this team is coming to Australia for the first few months of 2009.

In Canada a research team, rather than testing for the presence of EDCs in a lake, actually added 5–6 ng/L dosages of EE2 three times a week over about 20 weeks each year from 2001 to 2003. The exposure induced the production of the biomarker, the telltale intersex condition in males, and altered reproductive status in females. The overall effect was the near collapse of the entire fathead minnow population in the lake, which resulted in the study being ceased early. This outcome is a portent for wild fish populations elsewhere.

Studies in Australia

In the late 1990s both the New South Wales and Commonwealth governments identified the EDC issue as one that might be relevant for Australian environments. The low levels of dilution of effluent from sewage treatment plants, and the potential for EDCs, even in trace amounts, to adversely affect marsupials, were identified as priority areas for research.

Researchers have been working to obtain funding and develop methods to measure hormone levels and gauge effects in Australian waterways. Land & Water Australia funded CSIRO researchers in 2005 to study these levels and effects. The study showed that streams across Australia carry EDCs at concentrations that stimulate significant changes to the sexual cycles of native fauna, especially in catchment areas surrounding cattle feedlots, dairies and piggeries. EDCs can be expected at higher concentrations in sediments under anaerobic conditions, and this has implications for the reuse of water and biosolids. In fact, the researchers found that spreading wastewater on aerobic and biologically active soils can break down EDCs rapidly.

The LWA study found that levels of E1 in treated sewage from wastewater plants in the Australian Capital Territory and South Australia ranged up to 40 ng/L. Levels of E2 and EE2 ranged up to 4 ng/L and 1 ng/L respectively. If these effluents were to be discharged directly to the environment with minimal dilution (which is what happens in many locations around Australia) they would be present at some twenty times the acceptable level. The study also looked at run-off from intensive animal husbandry activities, since livestock excrete these same steroids. The levels of E1 and E2 found were similar to those detected in the wastewater plants. Again, the risk posed by discharging these concentrations into a waterway is about twenty times the acceptable level.

The Victorian Water Trust funded a number of surveys at sewage plants in their state. The most recent survey conducted in 2006–07 covered 45 plants out of a total 185 in the state. Just as in the LWA/CSIRO study, the VWT found EDC levels about twenty times the acceptable level.

Queensland studies funded by the Cooperative Research Centres for Water Quality and Treatment, Australian Research Council (ARC), and the New Zealand Water Environment Research Foundation found only two out of twelve plants had EDC levels above the detection limit.

In New South Wales, two research groups received funding from the Australian Research Council, Sydney Water and the University of New South Wales Engineering Department. One studied hormone levels in effluent from an enhanced primary plant (that is, minimal treatment) and the other monitored levels in an advanced tertiary treatment plant. Significantly, the treatment technologies at the advanced plant were found to reduce hormone levels below detection limits.

Additional points for consideration



- Hormonal effects are often masked by other toxic responses when testing at high doses. Only when testing is carried out at low doses do these effects become apparent. Furthermore, a feature of endocrine disruptors is the late occurrence of adverse effects long after exposure has ceased, or even effects in the next generation.
- Research is showing that mixtures of chemicals can compound effects that otherwise would not present when each component is present at a dose that individually does not produce effects. These observations further undermine the belief that threshold doses can be applied meaningfully during the safety assessment of chemicals.
- Internationally renowned environmental scientist Dr Susan Jobling has gone on record as saying that levels of aquatic EDCs recorded in Australia suggest that species living in the waterways studied would already be affected. She would support legislation that would bring Australian Government policy into line with those of Europe and the United States.
- Scientific uncertainty should not delay precautionary action to reduce risk. For the foreseeable future, regulation of EDCs will have to cope with the tension between the biological plausibility of irreversible damage and delays in generating data suitable for comprehensive assessment of risk.
- Though screening assays are not adequate as a basis for risk assessment, they should be used to trigger precautionary regulatory action on the basis that results may indicate risks. This is to offset delays on regulatory action as agencies screen chemicals to determine which require extensive testing. Precautionary action may include labelling, measures to reduce exposure, restrictions in use patterns and even a ban on certain chemicals.
- Steps should be taken to restrict the use of persistent chemicals such as brominated flame retardants in order to halt their build-up in humans and in the environment. Inaction may lead to a repeat of the events that led to the accumulation of dioxins and Polychlorinated Biphenyls in humans and wildlife.

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