Improving environmental protection policy: detection of sex-changing chemicals in the environment

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Contamination of our water supplies poses a serious environmental threat with detrimental effects on human health. Chemistry researchers at the University of Sussex have combined chemical fractionation and mass spectrometry techniques to identify endocrine-disrupting chemicals in wastewater effluents that are discharged into the environment and which accumulate in river sediments and the bodies of fish. This work has enabled international and governmental bodies to assess the risk to the environment posed by these compounds, to develop tests to monitor toxicity, and to inform policy decisions on environmental protection.

Overview

The contamination of water sources poses a serious threat to both the environment and to human health. Endocrine-disrupting chemicals (EDCs) are compounds that can interfere with the action of natural hormones in mammals and other vertebrates. These chemicals are mostly man-made and are commonly found in many different products – for example, in pesticides, food additives or contaminants, household products such as cleaning agents and personal-care products including cosmetics. EDCs have been associated with significant health problems, including certain cancers, altered reproductive development and function in both males and females, and in neurodevelopmental disorders. EDCs have also been shown to cause sexual dysfunction in fish, potentially affecting the health of some fish populations globally.

The work of Elizabeth Hill (Professor of Environmental Toxicology in the School of Life Sciences, University of Sussex) and her team of postdoctoral researchers and graduate students used bioassays combined with chemical fractionation and mass spectrometry profiling to identify EDCs present in wastewater effluents that are discharged into the environment and that bioaccumulate in fish. Professor Hill's group was the first to demonstrate that EDCs can bioconcentrate, many thousand-fold, in the bile of fish.

This bioaccumulation allowed the identification and monitoring of trace amounts of contaminants in surface waters. Furthermore, it enabled the identification of hormone-replacement chemicals as environmental oestrogens, which contribute to the oestrogen burden in fish and can cause feminisation of populations below discharges of wastewater effluents. Environmental oestrogens include a variety of synthetic or natural chemical compounds that mimic the female reproductive hormone oestrogen. Synthetic oestrogen mimics include widely used sunscreen agents and industrial compounds such as alkylphenols, chlorinated pesticides and bisphenol A. EDCs, including environmental oestrogens, have been implicated in numerous clinical problems including precocious puberty, disorders of both the male and female reproductive systems in humans and other animals, and in hormone-related cancers such as breast cancer.

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Using bioassay-directed fractionation and mass spectrometry analysis, they also identified the chemical structures of novel anti-androgenic contaminants that are present in wastewater effluents. The contaminants, which include triclosan and chlorophenes, are present in household disinfectants and were not previously recognised as having anti-androgenic activity – ie the ability to inhibit the action of androgens, which are natural hormones that stimulate or regulate the development and maintenance of male characteristics in vertebrates. Environmental anti-androgens have been shown to harm the development of male reproductive organs in newborn mammals and in juvenile fish.

Achieving impact

Professor Hill's research has had significant national and international impact in three key areas: on the European Union's (EU) regulation of EDCs; on the development of in vivo fish screening assays by the EU; and on the regulation of nonylphenol in the State of California in the US. The beneficiaries of Hill's work include government agencies responsible for environmental policy, the environment and human health and, ultimately, the populations who live under these regulations.

The finding that oestrogenic and anti-androgenic contaminants can accumulate in fish and impact their fertility and health, and that many of these chemicals persist in the environment, has been cited in a European Environment Agency Technical report. This report provided evidence that underpinned EU policy on EDCs and their regulation, specifically the European Commission's proposal to regulate levels of oestrogens in surface waters under recent revisions to the Water Framework Directive (2000/60/EC) in 2012. Some of Hill's research that was cited in this report was also presented in informal meetings with the UK's Environment Agency. In addition, a report by the Institute of Environment and Sustainability, of the Joint Research Centre of the European Commission cited Hill's work on the identification of anti-androgenic structures in wastewater effluents. The report collated information on chemical analytical methods for the new proposed Priority Substances under revisions of the European Water Framework Directive legislation.

In response to the identification of anti-androgenic contaminants in UK effluent, the Environment Directorate Chemicals Committee cited Hill's work as evidence for the need for in vivo fish-screening assays which, as a consequence, have now been developed by the EU.

Toxicokinetics describes the rate at which a chemical will enter the body and what happens to it thereafter in terms of metabolism, elimination and relative toxicity to the recipient. Hill's research on the toxicokinetics of nonylphenol – an EDC and environmental oestrogen – in fish was used to inform the risk assessment of this compound and has influenced State policy and regulation in California.

Future impact

The proposed regulatory levels for oestrogens under the EU Water Framework Directive (WFD) are based on the feminisation response of male fish to single compounds. However, Hill's group have recently found that mixtures of anti-androgenic chemicals, which are highly abundant contaminants in tissues of effluent-exposed fish, potentiate the feminised responses to oestrogens. Enhancement of oestrogen-induced feminisation of fish by anti-androgens commonly found in wastewater effluents would have direct implications for risk assessment of environmental oestrogens and the effectiveness of the proposed EU WFD regulation of oestrogens. Future work will help inform on the validity of the proposed regulatory levels for oestrogens to protect against feminising effects in fish and will inform on other chemicals that may need to be considered for regulation under the WFD. The work will contribute to environmental impact assessments and have importance in the regulation of discharges and, therefore, will be of direct benefit to the water industry, environmental, policy and regulatory agencies both in Europe and worldwide.

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Working with us

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For more information about Professor Hill's research, visit: **http://www.sussex.ac.uk/lifesci/hilllab/**