INTRODUCTION

Emerging chemical contaminants in water and wastewater

Recent advances in environmental analytical chemistry have resulted in an explosion of knowledge regarding the presence of previously undetectable chemical contaminants in water and wastewater. Many of these contaminants are anthropogenic, resulting from commercial products from human society and subsequently dispersed throughout the aquatic environment, passing between wastewater effluents, natural waters and drinking water supplies. While the environmental occurrence of these contaminants is usually very low (microgram down to subnanogram per litre), toxicologists, epidemiologists and risk assessment experts advise that there may still be significant and widespread adverse environmental and human health consequences (e.g. cancer risk and adverse reproductive development) at the observed levels. This new occurrence and environmental/human health information have raised the awareness of the global water industry, which is now assessing management practices and treatment technologies to effectively remove or destroy these contaminants. Regulators and water utility managers are also considering the most appropriate guidance and actions that will be in the best interests of the public and environmental health.

This Theme Issue of the Royal Society’s *Philosophical Transactions A* brings together inter-disciplinary perspectives on this topic, which represents a current challenge to the global water industry and is likely to be a significant issue of environmental and public health concern into the future. Addressing this challenge effectively will require contributions from environmental scientists and engineers, risk assessment experts, water utility managers and practitioners, toxicologists, epidemiologists and health scientists; therefore, this Theme Issue brings together views from leading international experts in each of these fields.

The impacts of endocrine-disrupting compounds (EDCs) and hormones on aquatic life have been the focus of much research, especially over the past decade. Prof. John Sumpter of the Institute for the Environment of Brunel University (UK) reviews the impact of chemicals on aquatic organisms and presents illustrative case studies to place the environmental challenges in context. Dr Olwenn Martin and Dr Nick Voulvoulis of the Centre for Environmental Policy at Imperial College London (UK) summarize the latest views on the risks associated with oestrogenic compounds in water and wastewater and practices to manage those risks. Dr Anna Comerton and colleagues from the Department of

One contribution of 12 to a Theme Issue ‘Emerging chemical contaminants in water and wastewater’.
Civil and Environmental Engineering at the University of Toronto (Canada) and from the University of Wyoming (USA) explain the modern analytical methods for detecting EDCs and other organic micro-pollutants in water and wastewater, and Prof. Walter Giger and colleagues from the Swiss Federal Institute of Aquatic Science and Technology (Eawag; Switzerland) describe the occurrence and fate of phenolic EDCs in wastewater and receiving waters.

Pharmaceutically active compounds that pass through the human body are transferred to wastewater and subsequently to receiving waters and drinking waters, owing to incomplete removal of these compounds by conventional treatment processes. In fact, it is not only over-the-counter pharmaceuticals that can be found in the environment, but also illicit drugs, as demonstrated by Dr Ettore Zuccato and Dr Sara Castiglioni of the Department of Environmental Health Sciences of the Mario Negri Institute for Pharmacological Research (Italy) in their review paper. Dr Mira Petrovic and colleagues from the Department of Environmental Chemistry, IDAEA-CSIC and partner institutions (Spain) discuss the fate and removal of these pharmaceuticals and illicit drugs by conventional and membrane bioreactor wastewater treatment, as well as by riverbank filtration, which is often described as a more ‘natural’ approach to treatment.

Many classes of organic micro-pollutants are removed, to a certain degree, by the activated sludge process in wastewater treatment, whereby the pollutants are transferred from the liquid phase (the water) to the solid phase (sludge). The resulting biosolids are, in many cases, spread on land as agricultural fertilizer. Dr Stephen Smith of the Department of Civil and Environmental Engineering at Imperial College London (UK) reviews the fate of organic contaminants in sewage sludge and the impact on agricultural recycling.

Disinfection by-products (DBPs) are another class of harmful compounds (e.g. carcinogens) that are formed from drinking water treatment processes themselves, such as through the reaction of chemical disinfectants (e.g. chlorine) with natural organic matter. Prof. Mark Nieuwenhuijsen of the Centre for Research in Environmental Epidemiology (Spain) presents the current epidemiological knowledge on chlorination DBPs in drinking water. Mr Stuart Krasner of the Metropolitan Water District of Southern California (USA) discusses the formation and control of a range of DBPs by water utilities. Prof. Howard Weinberg of the Department of Civil and Environmental Engineering at the University of North Carolina, Chapel Hill (USA) describes the state-of-the-art in analytical chemistry methods for detecting emerging DBPs in water.

Perfluorinated compounds are a comparatively new class of organic micro-pollutants that originate from surfactants and have been reported in environmental waters worldwide. Dr Paul Rumsby and colleagues from the National Centre for Environmental Toxicology, Water Research Centre (UK) provide a review of these compounds and discuss successful treatment approaches.

While it is clear from these papers that a large amount of excellent research has been conducted to date, it is equally evident that there is still much that must be better understood, such as how to assess the toxicological effects of mixtures of chemicals, how best to regulate these chemicals in the water industry and how to handle the degradation by-products and rejected water streams that result from the treatment of these compounds. The intention is that this Theme Issue will serve as a useful compilation of the current state of understanding regarding the
occurrence, formation and control of a range of emerging chemical contaminants in water and wastewater and can act as a jumping-off point for further research to better address this challenge into the future.

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