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Adverse Outcome Pathways in Aquatic Environmental Risk Assessment: Progress & Research Challenges

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Abstract - The historical approach to protecting human health and ecosystem quality from the adverse effects of chemicals is focused primarily on whole animal toxicity testing with individual chemicals of interest. As observed recently by the OECD (2013), due to the costs and time involved it is neither practical nor feasible to comprehensively test all synthetic chemicals that could affect human health and ecosystem quality using this traditional approach. Aquatic eco-toxicology developed internationally since the 1960s primarily using a whole organism approach, combined with expertise in chemistry, ecology and microbiology in order to restore polluted ecosystems and prospectively undertake toxicity testing on individual chemicals using individual model species. For example in European regulatory ecotoxicology, aquatic toxicity testing has often focused upon freshwater fish, crustaceans and algae and the combined results used to derive Predicted No Effect Concentrations (PNECs) for both freshwater and marine ecosystems. PNECs are then typically compared with Predicted Exposure Concentrations (PECs) and Measured Exposure Concentrations (MECs) in order to undertake an initial environmental risk assessment of the single chemicals of concern. In some cases refining the environmental risk assessment may require aquatic toxicity testing using a wider range of freshwater or marine species according to the pattern of use of the chemical of interest or in view of enhanced environmental exposure information (Hutchinson et al., 2013). Extrapolation from the model species included in the OECD Test Guidelines (e.g. chironomids, daphnids, zebrafish, etc.) to the wider ecosystem of interest is recognised to pose a major scientific challenge. A notable example of the scientific weaknesses of this historical approach is the unexpected long-term reproductive impacts on fish and invertebrates of oestrogens and other endocrine disrupting chemicals often discharged into lakes, rivers and coastal ecosystems. Over the past decade therefore the OECD Test Guidelines programme has markedly grown in order to address developmental and reproductive toxicity in amphibians and fish, while new test guidelines to assess the effects of chemicals on freshwater and marine molluscs are currently undergoing validation by several OECD member countries. In parallel with these developments to broaden the range of species used in aquatic ecotoxicity testing, there been major advances in recent years in the availability and application of toxicogenomics and other molecular tools in fish and other aquatic species. An excellent example is the increasing use of zebrafish in both biomedical research and in eco-toxicology, utilising the rapidly developing toolbox of genomic and cellular techniques available for this species. Encouraged by the progress being made in chemical safety testing to protect human health, many scientists working in eco-toxicology and environmental risk assessment and now embracing the Adverse Outcome Pathway (AOP) methodology to support regulatory toxicity testing and risk assessment (Ankley et al., 2010). It is important to recognise that the AOP concept uses existing techniques and links them with systems biology rather than being a completely new testing approach. In this context an AOP is defined as “a conceptual construct that portrays existing knowledge concerning the pathway causal linkages between the molecular initiating event and a final adverse effect at the biological level of organisation that is relevant to a regulatory decision” (Ankley et al., 2010; OECD 2013). Toxicogenomic tools are now available for a number of aquatic species used in the OECD test guidelines programme, notably fathead minnow, medaka, *Xenopus laevis* and zebrafish. However a critical challenge is the need for phenotypic anchoring data linked to the genomic responses in these species following defined exposures to a range of chemical classes of interest (e.g. agrochemicals, industrial chemicals and pharmaceuticals). The second major challenge is the need for the development and validation of toxicogenomic tools for use with freshwater and marine invertebrates. Finally in the field of aquatic eco-toxicology there is the need to continue to improve the basis for predicting and monitoring population impacts of chemical exposures based on single species laboratory studies (Hutchinson et al., 2013). A number of chemical case studies illustrating the progress being made for AOPs in aquatic organisms will be presented.

References

Ankley et al (2010) Adverse outcome pathways: a conceptual framework to support eco-toxicology research and risk assessment. Environmental toxicology and chemistry space 29:730-741.

OECD (2013) guidance document on developing and assessing adverse outcome pathways. OECD series on testing and assessment number 184. Reference ENV/JM/MONO(2013)6.