Mathematical modelling in ecotoxicology: an overview

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Keywords : concentration-response models; toxicokinetics-toxicodynamics models; matrix population models; food-web models

Target Session(s): Ecotoxicology

Abstract

Across the levels of biological organization, effects of chemicals can be very diverse, from DNA-damages within cells to shifts in trophic chains within ecosystems. When only focusing on intermediate levels, namely individual, population and community levels, environmental risk assessors already meet challenging issues, like the influence of chemical substances on individual life-history traits according to their mode of action, the resulting changes in species population dynamics and ecological interactions, until the potential repercussions in community structure and ecosystem functioning. These questions are today still made more complex due to increasingly numerous man-made chemicals at which living organisms are exposed, at low mixture concentrations hardly detectable and in combination with other environmental stress factors.

To unravel these inextricable situations, modelling is today become essential making environmental risk assessment of chemicals entering a new era. Indeed, reviews recently published by EFSA and OECD highlight the necessity of modelling, and specifically of mechanistic models, to conduct assessments that are not only ecologically relevant, but also more integrative and effective. For example, among mechanistic models recently developed at the individual level, toxicokinetic-toxicodynamic (TKTD) models are promoted to describe effects of chemical substances over time. TKTD models have many advantages in terms of mechanistic understanding of the chemical mode of action, deriving time-independent parameters, interpreting time-varying exposure profiles and making predictions under untested situations. Nevertheless, the population growth rate is today recognized as a more robust endpoint for assessing ecological risks of chemicals. Hence, capitalizing on the predictive power of TKTD models, they can be coupled with population dynamic models to predict chemical impacts at the population level. The final step consists in accounting for ecological interactions between species when the protection goal is to prevent a decrease in ecosystem services. For that purpose, large dynamical systems are required for which a large number of parameter needs to be valued, a particular big challenge at a scale where expriments are difficult, indeed impossible.

In this presentation, I will give an overview of several modelling approaches that revealed successful to answer scientific questions in the field of ecotoxicology, as well as to support the daily work of risk assessors in providing them with operational tools. I will illustrate my words based on examples at the individual, population and community levels, and suggest new challenging research questions for the future.

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