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CREAM: a European project on mechanistic effect models for ecological risk assessment of chemicals

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1 Aims and scope of CREAM

Current risk assessments are mainly based on ecotoxicological endpoints at the level of individual organisms, but according to the EU directives, the protection goal aims at achieving sustainable populations (European Commission 2002a, b; Forbes et al. 2009; Preuss et al. 2009a; Thorbek et al. 2009). Population-level effects depend not only on exposure and toxicity, but also on important ecological factors that are impossible to fully address empirically. At present, a number of testing approaches exist that provide endpoints on the community and the population level, respectively (nontarget arthropod and earthworm field tests, aquatic and terrestrial model ecosystem tests). However, not all fields and regulatory questions can be covered by these approaches. To fill these gaps and to enhance the scientific quality of ecological risk assessments, we suggest implementing mechanistic effect models (MEMs), as these also

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enable the integration of the relevant ecological factors, thus increasing the predictive power of ecological risk assessments as well as providing vital understanding of how chemicals interact with ecosystems. Such understanding is crucial for improving risk mitigation strategies and ecosystem management. By MEMs, we mean both ecological models that mechanistically represent key ecological processes (Bartell et al. 2003; Pastorok et al. 2002, 2003; van den Brink et al. 2007; Preuss et al. 2009b) and individual-level models quantifying adverse effects of chemicals on organisms based on mechanistic understanding (e.g., Ankley et al. 1995; Jager and Kooijman 2005; Ashauer et al. 2007). In these models, scenarios with and without effects of chemicals, for example, pesticides, on nontarget organisms are compared.

So far, however, regulators and industry have generally not had sufficient understanding to make use of the potential benefits that MEMs can deliver, and academics have been inconsistent in the approaches applied. In some of the—few—attempts to implement MEM in risk assessments in the context of national authorization procedures, the models have not been adjusted sufficiently precisely to the regulatory demands and have, therefore, not been accepted for the risk assessment. This has led to skepticism about the practicability of the application of models, preventing a wider use of MEMs in risk assessment. Therefore, examples that clearly demonstrate the power of MEMs for risk assessment are urgently needed, and industry, academia, and regulatory authorities across Europe need scientists that are trained in MEMs, principles of ecotoxicology, and regulatory risk assessment.

To meet these needs, Chemical Risk Effects Assessment Models (CREAM), a European project including 20 Ph.D. and three postdoctoral projects, has been launched for September 2009 and will last for 4 years. CREAM is a "Marie Curie Initial Training Network (ITN)" funded by the European Commission within the 7th Framework Programme. ITNs are part of the commission's "People" Programme and focus on mobility and first-class training of early stage researchers. CREAM is very likely the largest joint project worldwide developing MEMs for risk assessment of chemicals. The aims and scope of CREAM are:

1. Formulate and test guidance for Good Modeling Practice (GMoP) that ensures transparent and reliable decision support for chemical risk assessment.
2. Develop a suite of well-tested and validated mechanistic ecological effect models for a range of organisms and ecosystems relevant for chemical risk assessments.
3. Provide world-class training for the next generation of modelers, emphasizing transparency and rigorous model evaluation as core elements of models for decision support.

2 Consortium

CREAM includes 13 full partners and nine associated partners. The CREAM consortium represents the three main sectors involved in chemical risk assessment, i.e., academia (universities and research institutes in Denmark, England, France, Germany, Poland, Switzerland, and The Netherlands), large agrochemical companies (Syngenta, BASF, and Bayer CropScience), two consulting firms (RifCon and gaiac), and five regulatory authorities (United Kingdom, Germany, Spain, Sweden, and The Netherlands). Virtually all partners are active members of the Society of Environmental Toxicology and Chemistry (SETAC) and of the new SETAC Europe Advisory Group Mechanistic Effect Models for Ecological Risk Assessment of Chemicals ("MEMoRisk"; Preuss et al. 2009a). Thus, CREAM is a truly concerted action representing the critical mass and diversity in terms of sectors involved, countries, and individual projects.

3 Framework and projects

CREAM will include all relevant model types (i.e., differential and difference equations, matrix models, and individual-based or agent-based simulation models). The choice of model type and structure will follow consistent and logical principles. Guidance on GMoP for chemical risk assessment will be formulated with the aim of documenting important model design decisions, thereby making them transparent and reproducible. All individual projects will follow this GMoP, which will be based on five elements:

1. Modeling cycle: Developing models always follows the same sequence of tasks, independent of model type and problem addressed. The GMoP includes checklists for each of these tasks, which will be used for a concise but comprehensive documentation of the entire modeling process.
2. ODD protocol: For individual-based models, a general format for model description has already been developed (the Overview, Design concepts, Details protocol; Grimm et al. 2006). For CREAM, this protocol will be extended to include other model types so that all model descriptions follow the same format, e.g., present the model's elements in a certain sequence.
3. Rigorous model testing: Model evaluation includes four elements, which will be dealt with in a systematic and rigorous way: verification, sensitivity analysis, uncertainty analysis, and validation.
4. Combining different model types: Where possible, different types of models will be developed for the same

project and question. This is an innovative approach that will ensure consistency among model predictions of different model types, it provides a test of more complex models, and it allows clear demonstration of how understanding, predictive power, and required resources change depending on model complexity.

5. Model evaluation by peers: CREAM will implement and test evaluation procedures of model-based risk assessments. In the final phase of the project, all individual model documentations will be evaluated by other CREAM partners that were not involved in developing the model. This evaluation by peers aims at checking whether GMoP has been followed and thus serves, as for scientific publications, quality control and improvement.

The main research questions addressed by CREAM are:

- Recovery: How does population recovery depend on toxicity and ecological factors such as life cycle characteristics, species traits, population structure, density dependence, timing of exposure, and landscape structure?
- Extrapolation: How can we extrapolate from individual to population, from small scales to larger scales, from species to species, from one exposure pattern to another, and from certain environmental settings to different ones?
- Sensitivity: How does sensitivity at the individual level mechanistically link to impacts on populations, and to what extent can the linkages be extrapolated among species?
- Sublethal effects: What is the relative importance of lethal versus sublethal effects for controlling the population-level (and community-level) impacts of chemicals in the field?
- Model complexity: What level of model complexity is needed for different types of risk assessment questions?

CREAM includes five work packages: Aquatic Invertebrates; Terrestrial Invertebrates; Vertebrates; Good Modeling Practice; and Validation Data Sets. The 23 individual projects (http://www.cream-itn.eu) are all related to mechanistic ecological models, but about half of the projects also include, or even focus on, empirical work. Some of the projects are closely linked to each other.

4 Training

The foremost objective of Marie Curie ITNs is to offer fellows first-class training leading to excellent career options not only in academia, but also industry, authorities, and other sectors. As for mechanistic modeling, the demand for well-trained early stage researchers exceeds the current supply by far. CREAM's consortium includes a wide array of potential future employers who will be actively involved by cosupervising projects and offering internships. The CREAM projects will also be highly visible via: publications, release of guidance documents for GMoP, and presentations and short courses at SETAC and other conferences.

Most partner institutions in CREAM offer local graduate programs. In addition, CREAM will organize a series of training events, covering ecological modeling, statistics, database management, geographic information systems, software engineering, ecotoxicology, and risk assessment. Further training events will focus on complementary skills: making oral presentations, preparing a CV, writing grant proposals, writing papers for scientific journals and nonscientific audience, and poster presentations.

5 Contact

CREAM comprises a large consortium, but to fully achieve its objective to improve ecological risk assessment of chemicals by using MEMs, it needs to be part of wider networks of stakeholders involved in chemical risk assessment, including other continents. We are, therefore, very keen to exchange ideas and collaborate beyond the CREAM consortium. A main instrument for establishing first contacts is CREAM's website (http://www.cream-itn.eu). The website will give information about the project's progress; offer a WiKi database covering all relevant aspects related to MEMs for chemical risk assessment; and include a forum for discussions and posing questions. CREAM will be coordinated by Volker Grimm (volker.grimm@ufz.de).

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