MODELKEY

Models for Assessing and Forecasting the Impact of Environmental Key Pollutants on Marine and Freshwater Ecosystems and Biodiversity

The Challenge

Water is an inherited good that has to be protected and used in a sustainable way. Based on this understanding, the EU Water Framework Directive demands for a good ecological status of European waters by 2015. This is a challenging task for European water managers.

While hydro-morphological alterations and eutrophication are often quite obvious to impact the ecological status, toxic stress due to chemical contamination is more difficult to detect. The enormous complexity of possible contamination, a cascade of effects on different levels of biological complexity and the interaction with other stressors hamper the identification and assessment of toxic stress as a driving force for the impairment of the biological quality elements (BQEs) of the EU-WFD: algae, macrophytes, invertebrates and fish. Thus, MODELKEY had a specific focus on toxic pressure due to chemical contamination in the context with other factors and stressors such as habitat quality, nutrients and pathogens.

Project Objective

MODELKEY was designed to bridge knowledge gaps that impede the evaluation and mitigation of the causes for an insufficient ecological status in many aquatic ecosystems. Through a multidisciplinary approach, it aimed at developing interlinked and verified predictive modelling tools as well as state-of-the-art effect-assessment and analytical methods generally applicable to European freshwater and marine ecosystems.

In order to cover a broad range of European eco-regions three case studies covering the Mediterranean, Western European and Central European river basins Llobregat, Scheldt and Elbe, respectively, were identified. In order to even broaden this approach in a later stage, the Danube river basin was included for basin scale assessments. An extensive database including more than 5 million chemical, biological, habitat and ecotoxicity data from the four river basins were the basis for the selection of sites of interests for experimental and field investigations as well as for exposure, effect and risk modelling, and decision making.

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EATiP *Thematic Area of Relevance*

TA1: Product Quality, Consumer Safety and Health
TA2: Technology and Systems
TA3: Managing the Biological Lifecycle
TA4: Sustainable Feed Production
TA5: Integration with the Environment
TA6: Knowledge Management
TA7: Aquatic Animal Health and Welfare
TA8: Socio-Economics and Management

Key Words

Risk assessment, pollution research, aquatic ecosystems, river basin management plans, WFD, toxic chemicals, ecological status

Project Information

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Key Points

To achieve its objective MODELKEY was organised in six closely related sub-projects.

KEYTOX: Key toxicant identification
Tool development and application for effect-directed identification of site- and basin-specific key toxicants (including state-of-the-art effect assessment and analytical methods) for the establishment of cause-effect relationships and improved risk assessment.

BASIN: Basin specific database
Provision of a data distribution platform for the development and validation of tools and models within the other subprojects. An inventory of the state-of-the-art of monitoring data was also made as well as data-evaluation.

EXPO: Exposure modelling of contaminants
Establishment of easy-to-use exposure models for the prediction of risks of toxic pollution in river basins and adjacent coastal areas including modules on most relevant processes including sediment erosion and sedimentation, transport and fate, and bioavailability and food web accumulation.

EFFECT
Development of probabilistic and deterministic models to diagnose, predict and mechanistically simulate the ecological effects of exposure to toxic substances on community composition and food chain propagation.

SITE: Site Assessment and model verification
Development of tools and approaches to causal analysis of site-specific risks on biodiversity including sediment erosion and remobilisation analysis, bioavailability and biomagnification studies and effect assessment of communities on different trophic levels, including early warning systems based on in vitro effects and biomarkers and to provide a linkage to effect and exposure models at a site scale.

DECIS: Decision making / management
Development of a Decision Support System (DSS), which integrates the whole project deliverables in a framework to manage impacts of key pollutants on ecosystems and biodiversity.

Output Highlights

New evidences of toxic stress in aquatic ecosystems
Research in the different river basins provided strong evidence that contamination with toxic chemicals has a clear impact on aquatic communities and therefore on the ecological status of a water body. However, the impact of the toxic stress on the biological quality elements can only be detected if appropriate diagnostic tools are applied that show stressor-specific responses rather than general degradation only.

Impairment of ecological status results from the impact of multiple stressors
The risk imposed by multiple stressors to aquatic resources cannot be understood from assessing each individual stressor alone, but requires consideration of possible interactions and combination effects. To identify the hierarchy amongst the multiple stressors in order to prioritise remedial actions, the MODELKEY project developed different approaches including the application of: diagnostic experimental techniques, mechanistic experimental studies and models, multivariate methodologies, eco-epidemiological methodologies and stressor specific indices.

What to do if…? A tiered approach to assess impact of chemicals
The WFD forces water managers to invest in reaching a so called “good” chemical and ecological status of its water bodies by the end of the year 2015. However, the list of priority substances used to define the chemical status, contains only a small fraction of the chemicals that can be present in the environment and as a consequence the qualification “good chemical status” can never guarantee that the biological quality elements (BQEs) are not affected by toxic compounds. To help water managers to deal with this problem MODELKEY developed a practical flow chart that can be used as a guideline to assess whether toxic compounds affect the ecological status of a water body.

Modelkey suggests a field-evidence based approach to derive candidates for monitoring and prioritisation
To assess the impact of toxic effects on the Biological Quality Elements, MODELKEY developed an approach based on field relevance applying effect-directed analysis (EDA). This approach is complementary to the others in use and does not require any a priori knowledge on the enquired chemicals. It is based on measurable effects and thus specific for selected toxicological endpoints.

Considering bioavailability and bioaccumulation improves the assessment of chemical stress
A combination of modelling partitioning to different organic carbon phases and applying assessment methods to estimate freely dissolved (pore) water concentrations or exchangeable sediment concentrations seems to be the most cost-effective approach for underpinning management decisions. Despite the still considerable uncertainties in current methods to assess bioavailability, MODELKEY investigations clearly showed that retrospective risk assessment (of supposedly contaminated water bodies) should be based on extractable concentrations and freely dissolved concentrations rather than on total water or total sediment concentrations.

Modelkey suggests improvements for surveillance and investigative monitoring
One of the goals of the WFD was to harmonise monitoring strategies in Europe, which differed among countries or even regions with respect to e.g. parameters recorded or metrics applied for the same endpoint. The WFD distinguishes three different types, in a tiered and cost-effective basic design: surveillance, operational and investigative monitoring. MODELKEY developed innovative environmental assessment tools to support all three monitoring programmes to unravel unknown chemicals that might be responsible for the observed degradation.

Modelkey provides new integrated tools for risk assessment and decision making on a basin scale
MODELKEY investigated and applied different methods to predict toxic stress on the basis of measured concentrations in the field.

- The Toxic Units method offers the possibility to differentiate the predicted toxic stress between phytoplankton, macro-invertebrates and fish.
- The “multi-substance potentially affected fraction of species” (msPAF) directly quantifies the expected loss of species, taking into account mixture toxicity. Both methods use estimated bio-available concentrations.
- The SPEAR (SPecies At Risk) indicator expresses the share of invertebrate species sensitive to toxic stress within the total spectrum of species. Any significant reduction of this indicator, compared to a reference value of 50%, indicates possible effects from toxic stress.
- The EXPOBASIN model establishes spatial relations between causes (pollution sources) and downstream impacts (ecological risk, expressed as Toxic Units) to allow a spatial, quantitative and objective ranking of chemicals and/or pollution sources. The model can easily be applied to all European river basins.

The Modelkey Decision Support System supports river basin managers
The MODELKEY DSS is an innovative software system that combines several risk-based assessment tools (listed above) supporting river basin management. It allows classifying the ecological and chemical status of individual water bodies or (monitoring) locations. It prioritises hot spots by integrating environmental and socio-economic information. By identifying relevant causes of impairment (key stressors and key toxicants) and the most impaired biological communities (key ecological endpoints at risk) the DSS supports the set up of additional (investigative) monitoring and consecutive measures. The MODELKEY DSS is freely downloadable from the MODELKEY project website after registration.

Do projected management measures improve the ecological status? Combining Modelkey diagnostic tools with recent ecological methods opens up new opportunities for success prognosis
MODELKEY has clearly shown that toxic compound mixtures may cause deviations from the good ecological status (GES). At any specific site, many compounds and mixtures play a role within a complex multi-stress context. Thus, a suite of approaches and techniques was developed and applied in MODELKEY locally and on large geographical scales to diagnose and unveil those GES-relevant mixture impacts hidden so far. MODELKEY has proposed various methodologies for site-specific diagnosis of impact magnitudes and probable causes. While MODELKEY results provide a crucial step towards a holistic, receptor-based approach, these findings can be further expanded and deepened by combining them with recently developed, other promising eco(toxico)logical approaches and data.

The Full Report:
For a comprehensive description of the research project and for a copy of the final report, visit www.modelkey.org

Next Steps – Suggested Actions/Follow On

RTD

- Assessing the role of multiple stressors in ecosystem impairment and inferring causative agents is largely done on an empirical, case by case approach. What is needed, however, are more conceptual approaches providing a framework for an integrative – instead of solely chemical – risk assessment, i.e. the analysis, characterisation and possibly quantification of the combined risks to the environment from multiple stressors. Future research should build on that and develop tools that enable water managers to set hierarchies on the relative importance of stressors; find evidence of cause-effect relationships, and extrapolate multiple stressor effects across biological, spatial and temporal scales.

RTD

- MODELKEY research resulted in clear insights into future research needs. To further facilitate the drafting of cost-effective programmes of measures in Europe, the MODELKEY effect-oriented approach should be connected to a source-oriented approach (as e.g. applied in the project SOCOPSE), including the compilation of suitable inventories of diffuse sources of pollution. For some chemicals this may necessitate the integration of the environmental compartments water, air, ground water and soils in a spatially distributed fashion.

Related Publications/Projects

A full list of publications is available for download from www.modelkey.org
MODELKEY is closely linked to other national and European projects including European IPs ALARM, NoMiracle, and Aquaterra, and the STREP SWIFT-WFD.