N°7
OCTOBER
2010

Onema
MEETINGS

Mesocosms,
Their value as tools for managing the quality of aquatic environments

A symposium organised by Onema and INRA, with Total and Ineris.

Mesocosms are artificial ecosystems used by researchers and industrial companies to study the long-term effects of chemical substances on the structure and operation of natural aquatic ecosystems. Could these experimental platforms be useful for managing the functioning of natural environments, notably for establishing environmental quality standards and developing monitoring tools? Are they sufficiently representative for use in setting regulations? To discuss these issues, Onema and INRA, in conjunction with Total and Ineris, organised a symposium at Le Croisic from 14 to 16 October 2009.

Approximately 100 mesocosms exist worldwide, primarily in Europe, the U.S. and Australia. These experimental sites are artificial aquatic ecosystems of different sizes, true «scale models» of rivers or lakes set up outdoors. Artificial rivers are generally over 15 metres in length, whereas standing-water units range from a few hundred litres to a few hundred cubic metres. They contain living organisms from different trophic positions in the food webs and are exposed to natural environmental conditions. Mesocosms are self-sustaining systems, i.e. they can function without external inputs. They serve to measure the long-term effects of chemical substances on living organisms. To date, the most frequently studied substances are pesticides because mesocosms are often required to assess ecotoxicological risks prior to the market approval of the substances.

Could mesocosms also assist managers of aquatic environments? To answer this question, the symposium organised by Onema and INRA brought together experts in ecotoxicological-risk assessments (Afssa), in quality management of aquatic environments (Onema, Water agencies), from public research organisations (INRA, INEE-CNRS, Cemagref, IRSN, Ifremer, ENTPE) and from industry (Total Petrochemicals, Suez Environnement, Oréal, EDF, Véolia, Bayer CropScience).

Numerous advantages

Mesocosms complement biological tests in the lab for the assessment of the ecotoxicity of micropollutants in aquatic environments. They represent a compromise between the control and reproducibility of lab experiments and the ecological representativeness of field studies (see figure 2).

The discussions revealed the advantages of mesocosms, i.e. the capacity to 1) study simultaneously the fate and the direct, indirect and delayed (transgenerational) effects of toxic substances, 2) integrate the effects observed at different levels of biological organisation (cell, organism, population, community), 3) test various scenarios depending on the types of chemical substance, their mixtures, their route into the aquatic environment, as well as the frequency and level of exposure to the substances, 4) evaluate functional

© Inra - Rennes

By Véronique Poulsen, ANSES (Agency for food, environmental and occupational health & safety)

Mesocosms are often used for precise assessments of phytosanitary risks. When the potential risks have been identified by ecotoxicity trials in the lab, we turn to mesocosms which better represent the natural environment. They must contain at least the species (identified in the lab) most sensitive to the product and offer a high degree of biodiversity along the food chain. In addition, the studies must be representative of the farming practices advised for product use. That means they should use, where possible, the prescribed product dosage levels. The studies should also simulate multiple product applications, in terms of the dosage, the number of applications and the interval between each application. This enables more precise evaluation of organism exposure and the response of the simplified ecosystem. Finally, it is necessary to carry out the study under climatic conditions similar to those of the area where the product is used. This is because the external temperature impacts significantly on how the product reacts.

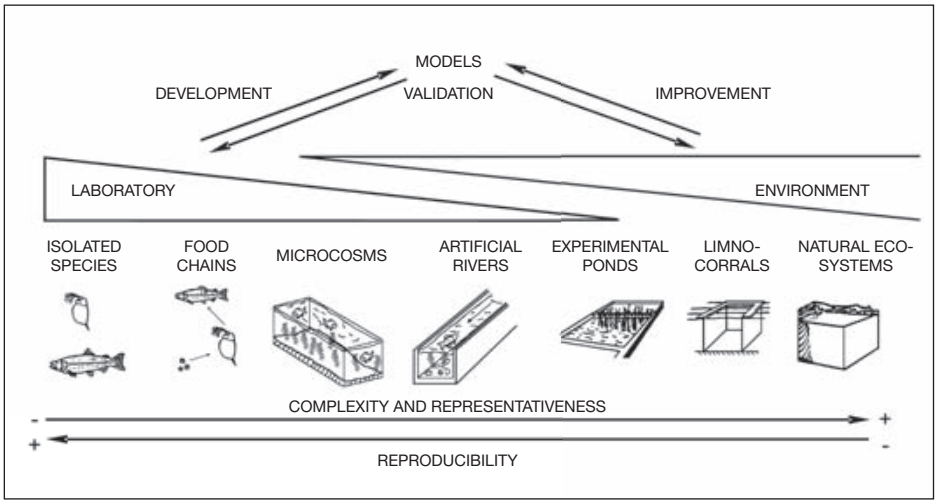


Figure : Main experimental systems used in environmental toxicology and ecotoxicology (Caquet et al., 2000).

impacts (changes in biomass, productivity, respiration), and 5) take into account, in certain cases, restoration dynamics of the impacted systems. In addition, it may be possible to partly control certain natural environmental factors that also influence the observed biological responses, or to test their effects on the fate and effects of contaminants. The experiment must be designed specifically to achieve the desired goal and requires contributions by several participants, namely the site owner, the project manager, experts, etc.

Mesocosms are already frequently used to prepare the regulatory documents for pesticide market authorisation procedures (see the info from Véronique Poulsen), but they are insufficiently used by managers in charge of evaluating and monitoring the quality of water and aquatic environments. Why? A number of reasons were identified during the symposium. In addition to occasionally insufficient awareness of mesocosms and their potential, it would appear that the complexity of their results and operation, notably compared to biological tests in the lab, constitute a major limitation to their use. The duration and cost of mesocosm experiments may also be a limiting factor.

The new outlook for use of mesocosms

The symposium identified a number of interesting potential uses of mesocosms for managers and produced several recommendations.

- Establish more robust environmental quality standards (EQS).

Mesocosms could be used to complement mechanistic approaches and/or lab experiments to define more robust environmental quality standards (EQS), incorporating ecological information. That is notably the case for hydrophobic substances (PCBs, certain organochlorine pesticides, polybrominated flame retardants) found in sediment or bio-accumulated in food webs.

By Thomas Pelte, Rhone-Mediterranean-Corsica water agency

Mesocosms are a very complex tool offering high potential for scientific and technical information, but it would seem that they are underused. They are regularly used for risk assessments in conjunction with phytosanitary-product authorisation procedures, but results are interpreted in terms of concentration levels not producing an effect and only a part of the data produced by a trial is effectively used. Conversely, the scientific work to understand ecotoxicological phenomena make relatively little use of mesocosms. We must identify the knowledge produced by these experimental systems and highlight them, e.g. their capacity to set certain biological indicators, characterise pollutant transfers in an ecosystem, contribute to modelling efforts. Currently, this technique has not yet found its «market», particularly since it can be relatively difficult and costly to use. The Water agency can assist Onema and scientists in identifying the knowledge-production processes in which mesocosms would be useful and in disseminating the information.

- Set up EQSs for substances representing long-term risks.

Mesocosms could be used to define EQSs for substances showing low acute toxicity, but significant risks over the long term, such as certain pharmaceutical substances and endocrine disruptors. This is because mesocosms can be used to study long-term ecological impacts (over several generations) and take into account the effects of degradation products of substances. Their role in the EQS-formulation process must be determined by the existing work groups on the national and European levels, similar to the process for risk assessments for pesticide market authorisations. It is also necessary to define a group of substances for which sediment and biota quality standards are urgently needed. Rather than using these systems for «old» substances that have already been regulated, it may be worthwhile to devote some effort to the study of emerging contaminants that have not yet been regulated.

By Thierry Caquet, INRA Rennes, member of the Onema scientific council

Restoration of contaminated ecosystems is an important element in assessing ecotoxicological risks. But ending exposure to a toxic substance is not sufficient for disturbed systems to return to their original state. Mesocosms are a means to better understand restoration processes. The work carried out at INRA in Rennes has shown that, in standing-water systems, the restoration of invertebrate communities depends on both recolonisation via other ecosystems (exogenous restoration, e.g. by insects) and the existence of dormant life forms in the contaminated mesocosms (endogenous restoration, e.g. by zooplankton). These results have fed into studies on the importance of connectivity between ecosystems in assessing ecotoxicological risks. Mesocosms are clearly a source of original and worthwhile information. But people are still reticent to use them, due notably to material limitations, including their cost. That is why it is important to make the most of each experiment and to set up networks for the existing experimental facilities.

- Optimise tools currently used for evaluation or monitoring.

Experiments using mesocosms are a chance to optimise tools currently used to evaluate the quality of aquatic environments, e.g. biocenotic indexes, notably by zeroing in on their field of application, for example by identifying limit conditions for use or analysing the effects of confounding factors. They can also serve to develop or validate monitoring tools, e.g. passive samplers, biomonitors and sentinel species, biomarkers of exposure and effects. In this field, mesocosms represent an experimental tool particularly well suited for comparing the response of biomarkers to the onset of detrimental effects on levels of biological organisation that are ecologically relevant (notably populations).

- Calibrate and/or test the validity of models

Mesocosms could also be used to calibrate and/or test the validity of ecotoxicology models, a rapidly developing field. This could be the topic of a national research programme, in conjunction with the European efforts already underway in this field. This type of model fully meets current needs for decision-aid tools. Another possible use would be in defining multi-criteria approaches to evaluating ecotoxicological risks.

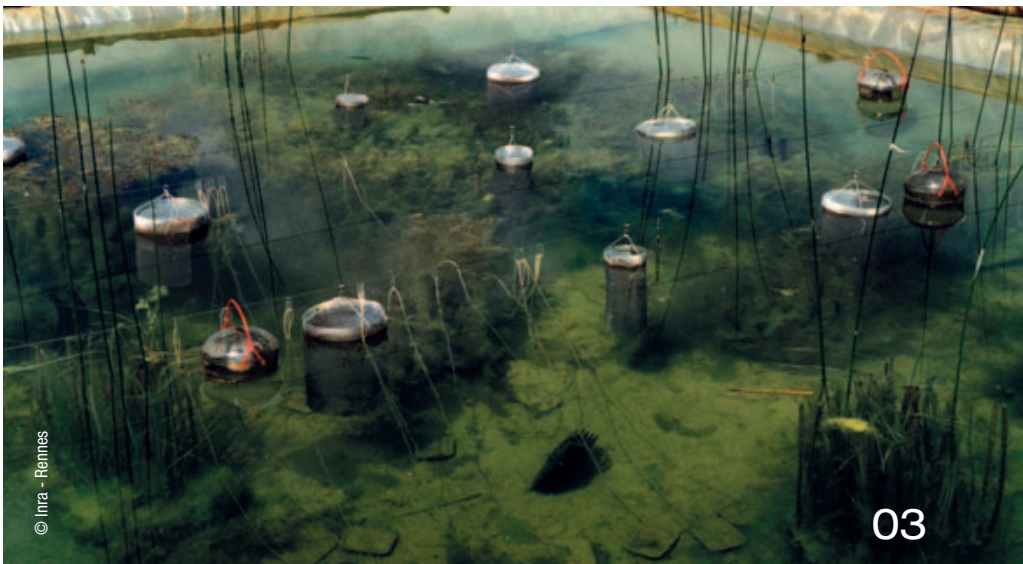
- Better understand restoration of aquatic systems.

Mesocosms could also be used to better understand the dynamics of aquatic-system restoration following a chemical disturbance and to define relevant criteria used to characterise restoration *(see info from Thierry Caquet).*

By Anne Bassères and Kevin Cailleaud, Mont/Lacq R&D centre, Environmental department, Total Petrochemicals

An aquatic mesocosm is an experimental unit used to mimic natural river systems. They are also known as artificial rivers. The mesocosms developed by Total in the Pyrénées-Atlantiques department resemble the natural environment because they receive fresh water and are naturally colonised. This type of system makes it possible to measure under controlled conditions the toxicity potential of substances/effluents. They are used for different types of studies, notably research and risk assessments of substances. The research deals with the development and validation of bioindicators for water quality and of alternative methods for WFD implementation. The risk assessments concern substances, for example in the framework of the REACH regulation. Threshold values, similar to the environmental quality standards, can also be set up for substances of interest to Total. The value of these experiments lies in their capacity to produce reliable and useful data because the mesocosms are similar to the natural environment and can thus address the issues confronting the industrial company following the recent regulations.


© Total


© Inra - Rennes

Recommendations made by the experts

At the end of the symposium, the experts recommended using the already available data. Meta-analysis could be carried out on one or more substances tested in mesocosms to evaluate the variability of results between different experimental platforms and identify synergies (or the lack thereof) between the platforms. It is also necessary to pursue the survey launched by the Institute for ecology and the environment (InEE / CNRS) on ecotoxicological experimental platforms in France, to have more information on the «mesocosm offering» available nationally. The need to establish a network between the existing experimental platforms was emphasised, notably to optimise acquisition of data in the various ecosystem compartments and to reduce the costs of experiments. To that end, a partnership structure, such as an official scientific group (GIS), could be set up. A second option would be to launch experiments involving multi-disciplinary teams.
Finally, efforts to communicate on mesocosms should be made to present their advantages and limits to managers of aquatic environments, and to demonstrate their potential in solving operational problems.

DR

A brief presentation of mesocosms

1. The point of a mesocosm is not to imitate a natural ecosystem. Mesocosms self-sustaining experimental systems in which different scenarios, set up to answer specific questions, can be tested. They complement lab tests and field monitoring, i.e. they are not intended as a replacement for tests and monitoring. Their use must be seen as one element in a wide range of approaches.

2. The questions that the mesocosm experiment should answer must be formulated together by the various stakeholders, i.e. the site owner, the project manager, experts, etc. System construction and the design of the experimental setup should take into account the questions to be answered and be optimised to facilitate multi-disciplinary approaches and to collect a maximum amount of information on the fate and the effects of contaminants in the aquatic ecosystems, including in terms of data processing and modelling.

3. In addition to substances that have already been regulated and for which the added-value of mesocosm experiments must be objectively evaluated taking into account environmental and social issues, a certain number of projects calling on mesocosms must be reserved for the study of emerging contaminants, notably those producing effects over several generations, in a collective organisation implementing different types of evaluation tools or monitoring systems.

4. Mesocosms are useful environments for testing advanced versions of new monitoring systems for the quality of aquatic environments and can assist in drafting their «user guides».

For more information…
www.onema.fr/
The recap of the symposium will be published on
www.onema.fr/IMG/EV/cat7a.html

Symposium organiser:

Olivier Perceval, Scientific officer for ecotoxicology

Onema MEETINGS
Publisher: Patrick Lavarde
Coordination: Véronique Barre, Research and development department, and Claire Roussel, Information and communication department
Author: Olivier Perceval
Editorial secretary: Béatrice Gentil
Translation: Cabinet Bartsch (info@bartsch.fr)
Layout design: Eclats Graphiques
Production: Accord Valmy
Printed on paper from sustainably managed forests by Panoply
Onema - 5 square Félix-Nadar
94300 Vincennes

ONEMA
Office national de l'eau et des milieux aquatiques