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Advances in (Environmental) Exposure Modelling: Bridging the Gap between Research and Application 4-5 May 2017, Brussels

Workshop Report No. 35

EUROPEAN CENTRE FOR ECOTOXICOLOGY AND TOXICOLOGY OF CHEMICALS

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Advances in Environmental Exposure Modelling: Bridging the Gap between Research and Application

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SUMMARY

Exposure models play an important role in the chemical risk assessment process as they provide valuable information regarding the exposure of chemicals to humans and the environment. This workshop was held to assess the current status of the science of environmental exposure modelling to identify areas for improvement and recommend practical steps to improve the current situation.

The following general principles of best practice in exposure modelling were identified:

- Regardless of the tool or model used, the applicability domains of models and the assumptions being made at different tiers should be clear.
- In a tiered approach (higher level) the application of other models should be considered to demonstrate consensus in the results.
- The role of a sensitivity analysis is crucial to identify which input data need improvement and a general effort should be made to develop input data of good quality to increase model accuracy (i.e. by developing strategies for monitoring program and use of monitoring data, etc.).

There is a need to develop a decision tree approach along with the corresponding rules of good practice for environmental exposure modelling across sectors.

Finally, a number of communication challenges have been identified to foster dialogue between industry and the broader stakeholder community. These are essential to ensure wider scientific and regulatory acceptability of proposed improvements in environmental exposure modelling.

"All models are wrong. Some are useful." (George E.P. Box, Statistician)

"Make things as simple as possible – but no simpler" (Albert Einstein, Theoretical physicist)

1. INTRODUCTION

1.1 Background

Assessing environmental exposure of chemicals used in commerce is a challenging, but critical part of assessing environmental risk. Approaches to assess exposure can vary between regulatory bodies. For instance, in Europe differences in estimating Predicted Environmental Concentrations (PECs) vary between general chemicals, regulated under Registration, Evaluation, Authorisation and restriction of Chemicals (REACH), biocidal products, regulated under the Biocidal Products Regulation (BPR, Regulation (EU) 528/2012), plant protection products (PPP), as defined by the PPP regulation ((EC) No 1107/2009), and pharmaceuticals, regulated by the European Medicines Agency. Nonetheless, a common objective is to ensure the assessment is transparent, robust, and utilises the latest advances in scientific developments, while at the same time providing a reasonable level of conservatism, necessary to account for associated uncertainties and natural variance in the environment that might influence the reliability of the exposure assessment.

During the last three decades, exposure models have played an important role in the assessment process, and when coupled with empirical data, they provide reliable information regarding the exposure of chemicals to humans and the environment. An important group of models that have evolved and are used within regulatory applications are the Mackay-type fugacity multimedia environmental fate models. Over the years several opportunities have arisen to reflect on the state-of-the-art, regarding the use of exposure models. Beginning in 1994, a workshop was organised by the Society of Environmental Toxicology and Chemistry (SETAC) at Leuven, Belgium, 14-16 April, 1994 and then again at Denver, Colorado, 4-5 November, 1994, which brought together 28 model users and developers to discuss the application of the models, to evaluate their performance, to provide guidance on their use, and to make recommendations on how the models could be improved in an effort to strengthen the broader acceptability and use of environmental fate models (Cowan *et al*, 1995). More recently, in Ottawa, Canada, 29-31 October, 2001, an OECD/UNEP Workshop was organised to assess the use of multimedia models for estimating overall environmental persistence and long-range transport in the context of POPs/PBTs assessment. This led to the publication of a number studies (Fenner *et al*, 2005) (Wegmann *et al*, 2009) and, in 2010, MacLeod *et al* (2010) published a feature article that reflected on the state-of-the-art in multimedia modelling at that time.

It is also notable that a number of related projects funded by Cefic LRI have also aimed to advance the application of exposure models in risk assessment, specifically, ECO3A-UTO[1], ECO3B-DELFT[2], ECO4-RIVO[3], ECO13[4],

[1] http://cefic-lri.org/projects/eco3a-uto-evaluating-multi-media-fate-and-transport-models-on-a-regional-and-global-scale/

[2] http://cefic-lri.org/projects/eco3b-delft-generic-estuary-modelling-system-to-evaluate-transport-fate-and-impact-of-contaminants-gemco/

[3] http://cefic-lri.org/projects/eco4-rivo-monitoringbase-collation-and-evaluation-of-monitoring-programmes-and-measured-environmental-concentration-data-on-organic-chemicals-in-european-aquatic-environments/

[4] http://cefic-lri.org/projects/eco13-development-application-and-evaluation-of-model-based-screening-procedures-for-pbt-chemicals-and-pops-screen-pop/

ECO21-ARC[5], ECO26-RAD[6], ECO31[7], EEM6-INTE[8], EEM6-UCRA[9], and EEM6-TECH[10]. In addition, ECETOC has published several technical reports in which the use of models features prominently, including ECETOC TR29 (ECETOC, 1988), TR50 (ECETOC, 1992), TR61 (ECETOC, 1994), TR67 (ECETOC, 1995), TR73 (ECETOC, 1997), TR74 (ECETOC, 1998), TR76 (ECETOC, 1999), TR82 (ECETOC, 2001), TR90 (ECETOC, 2003a), TR98 (ECETOC, 2005), TR111 (ECETOC, 2011a), TR112 (ECETOC, 2011b), and TR123 (ECETOC, 2013a), as well as three related workshop reports that primarily addressed persistence, WR24 (ECETOC, 2013b), WR10 (ECETOC, 2007), and WR1 (ECETOC, 2003b).

While there has been a great deal of resource directed towards activities aimed at advancing the use and application of exposure models, this ECETOC workshop of 4-5 May 2017 had as a key theme the review of exposure models used across the different industry sectors and regulatory bodies to identify synergies, as well as addressing challenges regarding uncertainty and applicability domain of the models. The workshop was held at the Pullman Brussels Centre Midi hotel, Brussels, Belgium.

1.2 Workshop structure and aims

This 2-day workshop was attended by sixty international scientific experts from industry, academia, regulatory agencies and consultancies that were invited by an ECETOC organising committee (see Appendix C).

The workshop provided the opportunity to bring together users and developers of environmental fate models used in assessing exposure, with an emphasis on the following key themes:

1. Review recent advances in exposure models, with a particular emphasis on targeting tools that help to better quantify uncertainties associated with both information gaps and the variance in environmental properties and emission scenarios generally understood as being key parameters requiring refinement necessary to strengthen confidence in PEC estimates.
2. Identify and assess feasibility of models and research capable of being representative of harmonised approaches for assessing exposure between the different industry sector groups, and which build on the strengths of the various approaches.
3. Address applicability domain challenges, including chemical, spatial, and temporal. To this end, research aimed at novel methods used towards improving estimates of emissions, developments in the handling of polar, ionised, and other chemicals with properties outside the applicability domain of existing exposure models. Also, to assess advances in tools aimed at integrating environmental fate models with ecological and/or effects models, either as screening-level or high-tiered tools.

[5] http://cefic-lri.org/projects/lri-eco21-arc-improving-the-performance-and-expanding-the-applicability-of-a-mechanistic-bioconcentration-model-for-ionogenic-organic-compounds-iocs-in-fish-bionic/

[6] http://cefic-lri.org/projects/eco26-rad-adapt-simpletreat-for-simulating-behavior-of-chemical-substances-during-industrial-sewage-treatment/

[7] http://cefic-lri.org/projects/eco31-identifying-strategies-that-will-provide-greater-confidence-in-estimating-the-degradation-rates-of-organic-chemicals-in-water-soil-and-sediment/

[8] http://cefic-lri.org/projects/eem6-inte-development-of-the-great-er-ii-extension-sediment-exposure-module/

[9] http://cefic-lri.org/projects/eem6-ucra-constructing-a-sediment-exposure-module-in-great-er/

[10] http://cefic-lri.org/projects/eem6-tech-develop-a-concept-for-externalising-databases-from-arcview-which-is-needed-for-great-er-2-0-to-allow-a-full-pan-european-development/

4. Discuss and capture advances related to the exposure assessment of chemical mixtures as well as tools capable of addressing the exposure of both the parent chemical and transformation products.
5. Identify best practices for addressing the influence of non-chemical stressors on chemical exposure.

Day 1 began with an introductory session comprising a series of expert presentations on exposure models applied within different industry sectors and regulatory bodies. This introductory session served to stimulate participant understanding of the range of exposure models and approaches, and to set the scene for the succeeding discussions in the break-out groups.

All participants were then split into four break-out syndicate groups to develop a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) that identifies factors that are helpful and harmful to achieving research and decision-making goals in four specific areas of exposure modelling expertise. NOTE: It was originally planned to have two syndicate sessions, one before lunch and one after lunch, but due to extensive discussions around the morning presentations only the afternoon syndicate session took place.

The conclusions of each of the four SWOT analyses were reviewed at the end of Day 1 by the Organising Committee to help distil key points. The goal of these SWOT analysis sessions was to identify key questions and opportunities for improving/developing exposure modelling, to be taken forward during the plenary feedback on the morning of Day 2.

This first day ended with an IT Modelling Fair, where some of the participants demonstrated exposure modelling tools and offered attendees some hands-on experience. The Modelling Fair was preceded by a short introductory session, chaired by Diederik Schowanek, in which model exhibitors presented 5-minute introductions to the models exhibited.

Day 2 began with a plenary session in which the rapporteurs from the Day 1 syndicate sessions presented the SWOT analysis and key questions and opportunities for improving/developing exposure modelling identified in their respective sessions. The plenary session was followed by a series of expert presentations on some more strategic, horizon-scanning aspects of exposure modelling.

Just prior to lunch on Day 2, Todd Gouin presented a summary of the key questions and opportunities for improving/developing exposure modelling, identified in the Day 1 syndicate sessions and reported in the Day 2 morning plenary session. These key questions were then pooled by the Organising Committee over lunch and the following four common themes were identified (along with a series of focused questions for each theme):

- Tiered assessment
- Communication
- Applicability Domain
- Decision tree on good practices

In the afternoon of Day 2, these themes and associated focused questions were explored and developed within four syndicate sessions. Rapporteurs from each syndicate session then reported on the discussions and identified paths forward/key research needs in a final plenary session.

2. PRESENTATION SUMMARIES

The welcome was given by Alan Poole (Secretary General, ECETOC, Belgium), who welcomed all attendees and provided an overview of the role of ECETOC as providing a scientific forum for expert collaboration, for example via the forum of a workshop such as this.

Todd Gouin (Chair of the Organising Committee, Unilever, UK) then presented some background to the workshop and outlined its motivations and aims:

1. Opportunity to reflect on the state-of-knowledge with respect to exposure models
2. Opportunity to bring together expertise across different industry sectors
3. Primary focus is the development and application of exposure models within the European regulatory framework, but taking into account the dynamic nature of the following three aspects: Environment, Chemical use, and Regulatory instruments.

Todd also referred to an upcoming special issue in the Royal Society of Chemistry Journal 'Environmental Science: Processes and Impacts (ESPI)', to be published January 2018, which will be dedicated to describing the latest advances in exposure modelling. Matt MacLeod (Stockholm University) gave a quick briefing on this RSC special issue, which he is working on in collaboration with some other participants of the workshop. At the time of publication of this workshop report, the special issue is already published (Environ Sci: Processes Impacts, 2018,20, rsc.li/modeling).

The following abstracts for the Day 1 and Day 2 presentations were drafted ahead of the workshop and have not been modified following the workshop discussions.

2.1 Day 1: Thursday 4 May 2017

2.1.1 Multimedia Fate and Exposure Models: Origins, Evolution, and Future Prospects

Dr Thomas McKone, University of California, Berkeley, USA

Key inputs to chemical risk assessments are the measurements needed to quantify emissions-to-dose metrics. But for a majority of chemicals in current use as well as for new chemicals we have limited information on use patterns and lack measurements of chemical concentrations in environmental media such as food webs and of human intake and tissue levels—creating a demand for models. Model-based efforts to assess human and ecosystem exposure to chemicals released to multiple environmental media have been evolving over five decades.

In this talk, McKone summarised the development and evolution of the multimedia mass-balance approach combined with multi-pathway exposure assessments as a framework for assessing the impacts of a broad range of chemical substances. Multimedia fate and exposure models provide comprehensive assessments that

synthesise information about partitioning, reaction, and intermedia-transport properties of chemicals in representative (local to regional) or generic (continental to global) environments.

In spite of questions about overall reliability, this approach provides insight on how chemical properties and use patterns map onto population-scale metrics of exposure, such as intake fraction for human populations and concentration/emission ratios for ecosystems. Although multimedia models cannot be truly validated, there is a rich history of model performance evaluation that has fostered confidence among regulators. Using a regional case study for pesticide alternatives in an agricultural valley of California, I will assess the opportunities and future prospects for the multimedia multi-pathway exposure framework.

This case reveals the dependence of intake/emissions ratios on (a) persistence of chemicals at different levels of integration (regional, urban-scale, food-web, indoors), (b) basic chemical properties, (c) the retention of chemicals in food webs, and (d) the retention of chemicals by indoor surfaces.

2.1.2 Development towards regulatory tools

Dr Mark Bonnell, Environment and Climate Change Canada

Several fate and exposure modelling approaches are being used by regulatory agencies across the globe in accordance with regulatory context. For example, Environment and Climate Change Canada (ECCC) and EU member countries employ exposure models for local or regional assessment while for treaties such as the Stockholm Convention on Persistent Organic Pollutants, continental or global transport models might be used. Thus, depending on the temporal and spatial scale of the evaluation and regulatory context of the evaluation, the choice of exposure approach and tools will vary.

However, because regulators are concerned with “chemicals that matter most” (ECHA) at different spatial and temporal scales it is important to ask how exposure science can help focus efforts on these chemicals. When referring to the ecological prioritisation of chemicals, for example, modelling of persistence (including transport) and bioaccumulation has traditionally been used as a surrogate for exposure on a wide scale, while individual chemical assessment has incorporated fate and exposure models for emission, waste treatment plant removal and distribution in the receiving environment on a local or regional scale. But as recently shown for the Canadian Domestic Substances List (DSL), including model generated exposure descriptors during the prioritisation of chemicals can alter the type and reduce the number of priorities for assessment compared with traditional hazard driven approaches.

Recently there have been “novel” applications of exposure models to fill data gaps and address uncertainty for exposure assessment as well as developments in exposure modelling that can benefit regulatory assessment by integrating exposure information from site of emission to site of toxicity.

2.1.3 Pesticide modelling within regulatory context

Krisztian Szegedi, BASF

The implementation of novel results in environmental models which are used in regulatory context is a necessary step of scientific development. However, the implementation process must fit in the strict framework of regulatory modelling and related version control.

Regulatory accepted models are being developed by independent research groups. Each model has a "general/research" version as well as a regulatory version. The general versions offer the highest flexibility and contain latest developments. Model changes are incorporated in parallel to the research progress of their authors. The regulatory versions of the models offer less flexibility: While substance and application related parameters can be freely chosen by the user, modification of scenarios is either not possible or not straightforward. Regulatory models undergo a strict version control, which is organised by FOCUS DG SANTE (FOrum for Co-ordination of pesticide fate models and their Use). The group controls the models from the scientific and technical point of view. Latest developments shall be included in the models after discussing them in the version control group. New model versions can be posted to the FOCUS DG SANTE homepage (http://eusoils.jrc.ec.europa.eu/projects/focus-dg-sante) only after detailed technical testing. This procedure ensures that models reflect scientific development, but the most important features in regulatory modelling are conserved.

The relevance of new processes must be discussed before their implementation in regulatory models. Moreover, latest developments have to achieve a certain maturity before they can be implemented in regulatory models: In contrary to confirmed and scientifically accepted results, new ideas and hypotheses might be still proven as false.

Accordingly, the following criteria can be proposed for the implementation of novel processes in regulatory models:

- General acceptance: More independent research groups shall work on the topic. Related publications have to be independently cited and must go beyond conference proceedings.
- Fit in regulatory framework: Processes must be discussed during development of guidance documents before their straight implementation in new model versions
- Version control: current good practice of version control shall be continued in the future.

Accepting the above proposed criteria as a practical guidance would ensure sustainable and smooth development in future regulatory modelling.

2.1.4 Pharma and use of exposure/fate models

Prof Jason Snape, AstraZeneca, UK

Human medicinal products are approved irrespective of environmental hazard and risk whereas Environmental hazard and risk is considered within the approval of veterinary risks (risk-benefit analysis).

The entry into the environment for HMPs and VMPs is distinct, with human medicinal products entering via WWTPs to surface water and biosolids application to land, and VMPs entering by direct emissions such as excretion of dung directly onto soil/into surface water and spreading manure on arable land.

The environmental risk assessment (ERA) of human and veterinary medicinal products is product-based and is carried out via a tiered system, with results from lower tiers determining need for further experimental data and higher tier assessments. The requirements and decisions regarding the tiered approach are different for human and veterinary medicinal products (HMP and VMP).

Most HMP ERA are worst-case, assuming, for example, no patient metabolism and no degradation or removal in STP.

Findings from a recent study on Worst Case Total PEC ERAs for HMPs were presented, followed by an Exposure Assessment Case Study for FOrum for Co-ordination of pesticide fate models and their Use which highlighted the importance of use of monitoring data in ERA.

A number of challenges associated with Pharmaceuticals ERA were presented, such as product vs substances assessments and access to consumption data.

2.1.5 ECHA Environmental Exposure assessment under REACh and Biocides

Dr Stefano Frattini, Scientific Officer, ECHA (European Chemical Agency), FI

The presentation focuses on key elements for environmental exposure assessment under REACH and Biocides regulatory regime.

For REACH, the emphasis is on releases where several methods exist to estimate emission to environment from point (industrial) sources and widespread uses. Since ERC release factors are very conservative, refinement based on reliable literature (e.g. Emission Scenario Documents by OECD) or sector knowledge (so called SpERCs) is often needed. The presentation will focus on development during last years and areas of improvement to get reliable (but still conservative) release estimation for exposure assessment under REACH.

The fate and transport model under REACH (and Biocides) is performed by EUSES model, while other models (e.g. CHARM or FOCUS) are rarely used and only in relation to very specific applications (e.g. coformulant in pesticides). Several areas of EUSES development have been identified and will be shortly discussed[11] (e.g. model to evaluate direct releases to soil, implementation of more advanced simpletreat 4.0 model in EUSES). Moreover, applicability of EUSES to specific type of substances such as metals will be also covered in the presentation (e.g. man via environmental EUSES estimation for metals).

[11] See also ECHA publication on "Identification and preliminary analysis of update needs for EUSES – RIVM" available at: https://echa.europa.eu/documents/10162/13630/echa_2014_253_euses_report_en.pdf/35a43ff6-4186-4c82-b1fd-8a7742cbfcdf

Biocides and REACH regulatory regimes are very similar with the reference to environmental exposure and risk assessment. Specific needs and peculiarities of Biocides in relation to environmental exposure assessment will be also highlighted during the presentation.

2.1.6 The Role of Fate and Exposure Models within P & B Assessment

Prof. Dr Martin Scheringer, Masaryk University in Brno, CZ and Swiss Federal Institute of Technology (ETH) Zurich, CH

Fate and exposure models are an important element in the assessment of the P (persistence) and B (bioaccumulation potential) properties of chemicals. Regulatory persistence criteria are defined in terms of single-media half-lives. Multimedia fate models make it possible to integrate information on single-media half-lives with the phase-partitioning properties of a chemical and to calculate the chemical's overall persistence, Pov. In contrast to single-media half-lives, Pov reflects the environmental fate of a chemical, but has the disadvantage that it depends strongly on the emission pathway (mode-of-entry) of the chemical. This problem can be overcome by another model-derived metric of persistence, which is the persistence in the Temporal Remote State (TRS). The TRS persistence describes how rapidly (or slowly) the most long-lived reservoir of a chemical in the environment disappears.

It is independent of the emission pathway; a good estimate of the TRS persistence is obtained if the overall persistence, Pov, is calculated for different emission pathways and the highest Pov value is taken[12]. The OECD Pov and LRTP Tool is a user-friendly software that incorporates this approach.

In addition, the Tool offers a comprehensive sensitivity and uncertainty analysis for the persistence and long-range transport potential of a chemical[13]. Complementary to these generic model applications in determining P is the use of models to analyse and interpret data measured in degradation tests, such as the modelling work for the OECD 308 aquatic sediment biotransformation test[14].

Regarding bioconcentration, multimedia fate models can be used to estimate bioconcentration factors (and levels in biota) if a compartment representing exposed organisms, e.g. fish in a lake, is included. Also, more detailed bioaccumulation models for cows and humans are available[15].

Overall, multimedia mass-balance models have been used in multiple ways to determine the P and B properties of organic chemicals and to generate a mechanistic understanding of the processes that influence these properties.

[12] Stroebe, M., et al., Measures of Overall Persistence and the Temporal Remote State, Environmental Science & Technology 38 (2004), 5665–5673.

[13] Wegmann, F., et al., The OECD software tool for screening chemicals for persistence and long-range transport potential. Environmental Modelling & Software 24 (2009), 228–237.

[14] Honti, M., Fenner, K., Deriving Persistence Indicators from Regulatory Water-Sediment Studies – Opportunities and Limitations in OECD 308 Data, Environmental Science & Technology 49 (2015), 5879–5886

15 McLachlan, M.S., et al. Bioaccumulation of Organic Contaminants in Humans: A Multimedia Perspective and the Importance of Biotransformation, Environmental Science & Technology 44 (2011), 197–202.

2.2 Day 2: Friday 5 May 2017

2.2.1 Recognising the important role of exposure models in characterising risk in the 21st Century

Dr Jon Arnot, President of ARC – Arnot Research and Consulting and Adjunct Professor at University of Toronto, CA

Several scientific and regulatory programs seek to advance and incorporate methods and data streams from exposure science, toxicology, and epidemiology to better understand mechanistic processes and evaluate the potential risks of chemicals to humans and the environment.

The United States National Academies of Science, Engineering, and Medicine established an ad-hoc Committee on Incorporating 21st Century Science into Risk-Based Evaluations that resulted in a published report ("NAS R21", January 2017). The NAS R21 report considers the scientific advances that have occurred following the publication of the Academies' reports "Toxicity Testing in the 21st Century: A Vision and a Strategy" (Tox21) and "Exposure Science in the 21st Century: A Vision and a Strategy" (ES21). Given the various ongoing lines of investigation and new data streams that have emerged, the NAS R21 publication proposes how best to integrate and use the emerging results in characterising chemical risk. While the NAS R21 report focused on exposure assessment and modelling for human health assessments. These approaches are generally applicable to ecological assessments as well. This presentation summarises exposure modelling material presented in the NAS R21 report including a summary of key developments in exposure science since the ES21 report as well as key development opportunities for the field of exposure science recommended by the committee.

Case studies and examples included in the NAS R21 re-port and additional case studies are also presented.

2.2.2 Thoughts from Europe – Roskilde workshop

Dr Henriette Selck, Roskilde University, DK

Many have experienced that their quality of life has improved over the past century in particular due to technological developments. Human developments have in combination with the simultaneously exponential population growth negatively impacted many of the world's ecosystems through over-exploitation of natural resources, pollution, and changes to the climate system. Consequently, ecosystems are experiencing multiple risks (natural hazards, anthropogenic hazards, climate change). Currently we assess risk for different stressors individually with risk-assessment frameworks that are not easy to integrate and that typically disregard other stressors. The international workshop ''Environmental Risk – assessing and managing multiple risk in a changing world' held in Roskilde, November 2015 was organised based on an identified need to improve our current approach to assessing environmental risks to humans and ecosystems. Thirty participants from 9 countries attended the workshop and their consensus recommendations regarding assessing and managing multiple risks in a changing world were published as an ET&C Focus paper (Selck *et al*, 2017). This presentation

will, with point of departure in the workshop paper, discuss the importance of considering multiple stressors in exposure and fate models.

The second part of the presentation is focused on examples illustrating how existing risk assessment tools may be challenged regarding hydrophobic organic compounds. Current risk assessment of contaminants is based on these contaminants' potential to persist (P) in the environment, bioaccumulate (B) in biota and their potential toxicity (T). Historically, environmental risk assessment (ERA) has focused on the water compartment with the assumption that only dissolved contaminants are available for uptake in biota, and a fundamental premise of assessing bioaccumulation potential has been the application of a lipophilic model (e.g., the octanol/water-partitioning coefficient: log K_{OW}) which has often been considered sufficient to estimate bioaccumulation. I will show examples illustrating that existing risk assessment tools and methods are not designed to fully address contaminants, such as hydrophobic organic contaminants, because: sediment-associated contaminants are available for uptake in biota and often exceed uptake from the water phase in sediment-dwelling organisms, and the potential capacity of benthic invertebrates to metabolise organic contaminants (i.e. biotransform) can be higher than microbial degradation. These factors are likely to impact the fate of sediment-associated contaminants.

2.2.3 Strategies to provide human biomonitoring trend data for exposure modelling

Dr Jochen Mueller, The University of Queensland, AU

Exposure to chemicals is associated with adverse health effects in highly exposed and/or vulnerable population subgroups. Exposure to chemicals in the general or specific populations (or individual) may be determined by the collection and analysis of blood serum and/ or urine (i.e. biomonitoring). Such data have become crucial tools for government policy makers in the legislation and regulation of chemicals. It is also a good starting point to identify exposure trends and understand changes and factors that may be associated with exposure and/or concentration trends.

In 2002, we established a cross sectional human biomonitoring program using de-identified surplus pathology serum samples designed to capture exposure trends in the Australian population. Two-yearly collection and analyses in this program has resulted in temporal trend analyses of numerous chemicals. The program has been expanded to include sampling of specific sub-groups (based on age, exposure or socio-economics) and has been expanded to sampling of urine.

Furthermore, in 2009 we commenced systematic sampling and analysis of wastewater as an additional tool for obtaining exposure data from entire populations in catchments. Data from these programs have proved useful to exposure modelling including retrospective evaluation of exposure peaks and trends and provide baseline data for many studies that target potentially exposed groups. New projects further aim to gain insight in spatial patterns that may be linked to population health outcomes and specific disease patterns.

2.2.4 Planetary boundary threats from chemical pollution

Dr Matthew MacLeod, Stockholm University, SE

In a 2009 paper published in Nature, Rockström *et al*. proposed a set of planetary boundaries that partially define a "safe operating space for humanity". Exceedance of the planetary boundaries threatens to push the Earth system outside of the stable, Holocene-like conditions that have fostered development of human society. Five of the planetary boundaries identified in the 2009 Nature paper are related to effects of chemical agents on vital Earth system processes. Other chemical pollution-related planetary boundaries likely exist but are currently unknown.

This presentation will outline approaches to identifying and defining planetary boundaries for chemical pollution that have been developed since 2009. Scenarios in which chemicals could pose a planetary boundary threat, and chemical profiles of potential threats will be developed and discussed. The chemical profiles depend on the nature of the effect of the chemical and the nature of exposure of the environment to the chemical. Prioritisation of chemicals in commerce and new chemicals that are being brought to market against some of the profiles is feasible and could be supported by fate and exposure modelling.

However, there are considerable uncertainties and scientific challenges that must be addressed. Most challenging is prioritising chemicals in the face of ignorance about their potential to have a currently unknown effect on a vital Earth system process.

The most effective strategy is likely to be prioritising chemicals against planetary boundary threat profiles and continuous monitoring of the biogeochemical processes that underlie vital Earth system processes to identify currently unknown disruptive effects.

3. BREAKOUT SESSIONS

Break-out sessions for syndicate groups were held during the afternoons of Day 1 and Day 2.

See Appendix A for details of the programme and syndicate group assignment.

3.1 Day 1 SWOT analysis of modelling approaches for four industry sectors

On the afternoon of Day 1, all participants were split into four break-out syndicate groups to develop a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) to identify factors that are helpful and harmful to achieving research and decision-making goals in four specific areas of exposure modelling expertise:

1. General Chemicals and Biocides
2. Agrochemicals
3. Pharmaceuticals
4. Hazard P/B assessment

The goal of each syndicate session was to generate meaningful information within each of the categories of the below 2X2 SWOT matrix (see Figure 1). Some examples of questions that could be addressed in the SWOT analysis were also provided (Figure 2) with the intention to help identify the key questions and opportunities for improving/developing exposure modelling.

Figure 1 : « SWOT » matrix

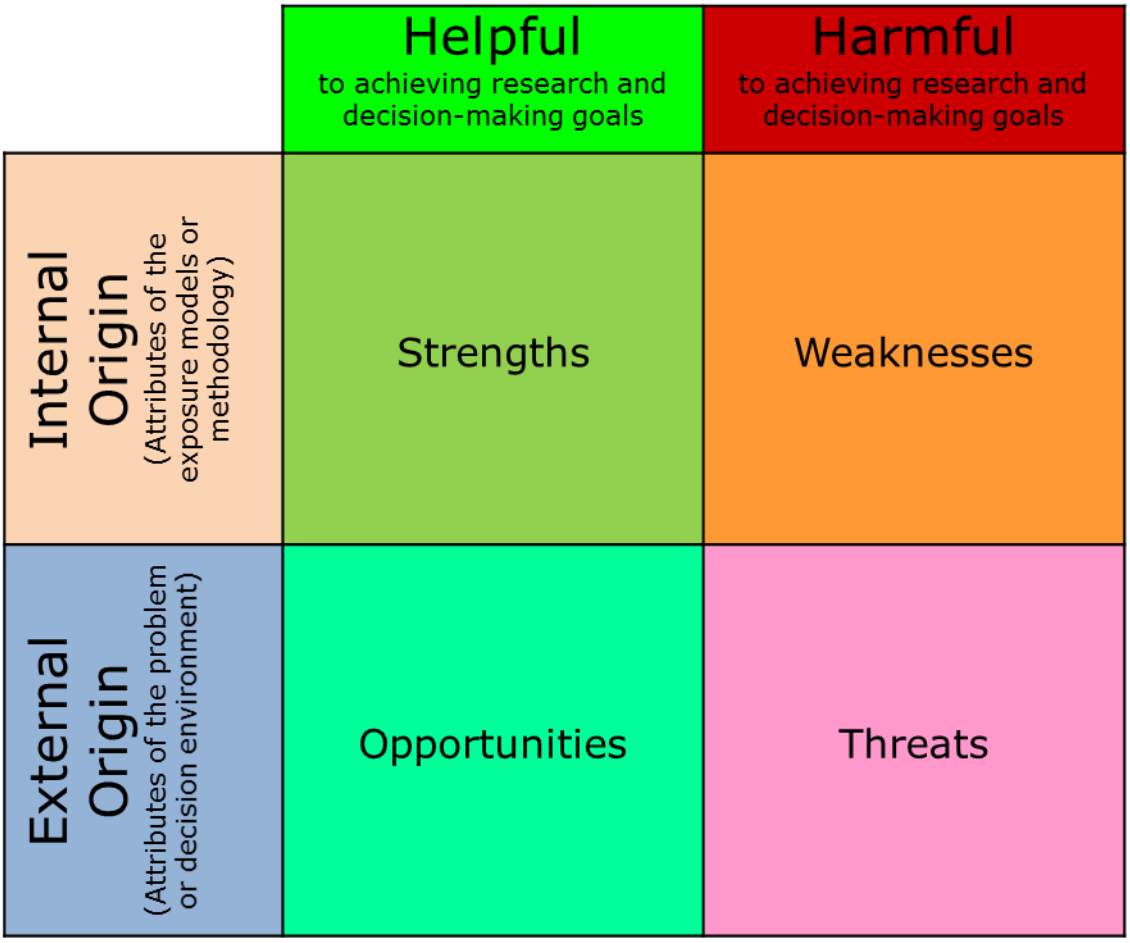

Figure 2 : Some examples of questions that could be addressed in the SWOT analysis

Strengths	What do other people see as your strong points? What resources do you have access to?
Weaknesses	What aspects of your models do you see as sub-standard? What kind of problems do you avoid? What are your limitations?
Opportunities	What are the interesting trends in the field? Where or what are there good opportunities for development? Changes in policy?
Threats	What are the reasons others give for ignoring your modelling results? Are there significant changes in the requirements conducting model analyses?

Prior to the workshop, the participants had been allocated to one of the following four syndicate groups, according to their expertise and area of interests, and received a set of questions from their respective moderators/rapporteurs, to stimulate the discussions:

- General Chemicals and Biocides (**moderator**: Johannes Tolls, Henkel and **rapporteur:** Graham Whale, Shell)
- Agrochemicals (**moderator**: Melanie Kah, Univ. Vienna and **rapporteur**: Krisztian Szedgedi, BASF)
- Pharmaceuticals (**moderator**: Jason Snape, Astra-Zeneca and **rapporteur**: Jason Weeks, independent)
- Hazard P/B assessment (**moderator**: Martin Scheringer, ETH Zürich & Masaryk University and **rapporteur**: Miriam Leon Paumen, ExxonMobil)

The following sections set out the SWOT analyses and the key questions and opportunities for improving/developing exposure modelling, as identified in each of the four syndicate groups and presented by the rapporteurs during the Day 2 morning plenary session.

3.1.1 General Chemicals/Biocides

Moderator: Johannes Tolls (Henkel), rapporteur: Graham Whale (Shell)

Available models in this area were first identified and introduced, i.e. The REACH R16 / TGD-Model (EUSES, ECETOC TRA, PetroRisk...), MERLIN-Expo, GREAT-ER, USEtox, PiF, Pangea, SPERCs, Biocide ESD, OECD ESD, CHARM i-STREEM, etc. Some key considerations were then identified for selecting the appropriate model and applying it correctly, such as clear identification of objectives (i.e. what are we trying to achieve) and clarity on the boundary conditions of models used (especially when considering tiered approaches). It was agreed that a decision tree could be helpful to aid this process.

Spatially explicit models (e.g. GREAT-ER, Pangea) and scenario-based deterministic models (e.g. CHESAR/EUSES) were considered separately, and commonalities/discrepancies of those models were identified.

For spatially explicit models, the following considerations were raised:

- GIS models should be used for higher tier model.
- GIS is an effective visualisation tool that helps in communication.
- GIS and spatial explicit models can be linked to effects seen e.g. endocrine hotspots in Water Framework Directive monitoring.
- Those models can still be used for point sources e.g. in GREAT-ER the waste water treatment plants are in effect the point sources.
- The spatial (and potentially temporal) resolution is much greater than scenario-based models.

- The degree of resolution of the models needs to be adapted to the objectives and to fit the chemical properties.

- The regulatory acceptance varies, but these models have been used to provide data in discharge permit applications.

- These models rely on emission inventories, either data and/or assumptions, but there is much more data now than 10 years ago (use of 'big data' is a possibility).

- Probabilistic models can be incorporated in order to characterise variability and uncertainty.

The SWOT analysis of spatially explicit models is presented in Figure 3 below:

Figure 3 : SWOT matrix of spatially explicit models used for General Chemicals/Biocides

Strengths	• Very accurate • Probabilistic model strength • Provide context to exposure/risk • Provides spatial and temporal changes to exposure • Able to characterise specific scenarios • Easy to move to probabilistic assessment • Easier to link with validation via monitoring
Weaknesses	• Data intensive • Global modelling • Uncertainty on how guideline fate studies inform fate in different climate • Emissions need to be well defined • Probabilistic model weakness • Regulatory interpretation • Regulatory acceptance for REACH/BPR
Opportunities	• Use data from Water Framework Directive • Opportunities for use of "big data" (2 comments)
Threats	• Heterogeneous data sets across Europe or world • Difficulties (not so easy to do) multimedia at high resolution

For scenario-based models, the following considerations were raised:

- Models are non-spatial and deterministic.

- Models such as EUSES are in effect a conservative screening tool, and should be recognised as such, i.e. such models should be built into tiered assessments, with simple data requirements and defaults used at a screening stage which assesses need for higher tiers. Limitations should be acknowledged and communicated in a clear and transparent manner along the way.

- The EUSES model needs improvement, and there are concerns regarding lack of transparency when using it via CHESAR. These models also need a sensitivity analysis to understand where data inputs

(e.g. chemical properties, equilibrium partitioning, persistence) are critical in terms of model outputs (the new version of CHESAR should help with this).

- There are concerns with sediments effects data in EUSES, especially for biocides, because of the concept of instantaneous absorption onto sediment particles.

- There may be more benefit in developing models/approaches to better understand the emissions as this appears to be one of the greatest weaknesses of most models.

The SWOT analysis of deterministic scenario-based models is presented in Figure 4 below:

Figure 4 : SWOT matrix of deterministic models used for General Chemicals/Biocides

Strengths	• Supports screening assessment • CHESAR easier to use • ECETOC TRA batch processing possible • Generic • Well known • Provides consistent basis • Regulatory accepted (2 comments) • Scenario data not required (already includes default) • Tier 1 screening
Weaknesses	• Not designed to deal with ionic/ionisable chemicals (2 comments) • Does not work for metals • Application to local scenario • CHESAR not flexible enough • There are fixes required • Does not contain latest science (needs to be updated based on recent science) • One scenario used to cover all situations in EU • Needs updating • Scenarios often overly conservative • Limited to TIER 1 assessment • Very conservative approach to PEC at local scale
Opportunities	• Updates available for EUSES need to be implemented • Revision of tool to include SimpleTreat 4.0 • Could benefit from a more tiered approach • Need to expand the regulatory toolbox beyond EUSES • Model formulations need to be updated with latest science • Does it all if needed • Support Stefano's list of updates (not exhaustive)
Threats	• Conservative with no flexibility • Not making EUSES fit into a mould it wasn't meant for • Numbers taken at face value without describing screening nature and limitations

The recommended next steps for improving/developing modelling for general chemicals/biocides risk assessment were identified and are listed below:

- Decision tree for model selection

Understanding the initial objective of what the assessor is trying to achieve is key for deciding which model to use and how to apply it. A decision tree should be constructed to aid this process. The decision tree should include, among other considerations, an assessment of the sensitivity of the model to various data inputs, the boundary conditions of the models, the scope of emissions (i.e. point source industrial emission vs wide dispersive use) and the type of chemicals being assessed (some chemicals are not appropriate for 'standard' models e.g. UVCBs and ionisable chemicals).

- EUSES improvements

There is a need to work with ECHA and other stakeholders to 'take a step back' regarding EUSES and to revisit the model and its purpose, particularly with emphasis on lower tier risk assessments (i.e. build in some pragmatism, including tier zero approaches). This initiative could be kick-started by a workshop to identify the EUSES update needs. Any revisions need to relate to CHESAR which has been designed to simplify the process of using EUSES. Developing models/approaches to better understand emissions is key, as this appears to be one of the greatest weaknesses of most models. The SWOT analysis output from this syndicate session can be used to communicate where improvements/revisions should be focused.

3.1.2 Agrochemicals

Moderator: Melanie Kah (Univ. Vienna), Rapporteur: Krisztian Szedgedi (BASF)

The following set of questions were circulated prior to the workshop and were the basis for the discussions and SWOT analysis:

1. Are environmental processes appropriately described?
2. How could the process of acquiring fate model inputs be improved?
3. How well are uncertainties dealt with?
4. Is the balance between realism and pragmatism adequate for the purpose?
5. Has harmonisation been successful (and advantageous?) so far?
6. Is the applicability domain of current tools matching their use? (e.g. type of chemicals, geographical areas, temporal scale). Could/should they be applied to other domains?
7. Are emissions/application rates of pesticides adequately estimated?
8. Are monitoring data/field studies considered to a sufficient level?

The 'condensed' SWOT matrix

The SWOT analysis of Agrochemical models is presented in Figure 5 below:

Figure 5: SWOT matrix of models used for Agrochemicals

Strengths	• High confidence by users and regulators • Transparency by users and regulators • FOCUS models well received among stakeholders
Weaknesses	• Spatial variability not addressed adequately • Temporal variability not addressed adequately
Opportunities	• Recalibration of lower tiers • Multimedia models
Threats	• Environmental mixtures • Risk of losing parsimony in modelling and credibility in risk communication

The most important topics/key questions were identified via voting and were as follows:

- Is the balance between realism and pragmatism adequate for the purpose?
- Has harmonisation been successful (and advantageous?) so far?
- Is the applicability domain of current tools matching their use? (e.g. type of chemicals, geographical areas, temporal scale). Could/should they be applied to other domains?

3.1.3 Pharmaceuticals

Moderator: Jason Snape (Astra-Zeneca), Rapporteur: Jason Weeks (Independent)

The session aimed to review the strengths and weaknesses of the regulatory guidance for exposure assessment of human and veterinary medicinal productions (HMPs and VMPs), to identify the opportunities to improve exposure assessment within the existing guidance, and to identify the key exposure science needs for this community that will address critical uncertainties.

The SWOT analysis of Pharmaceutical models is presented in Figure 6 below:

Figure 6: SWOT matrix of models used for Pharmaceuticals

Strengths	• Huge knowledge base • FOCUS works well for VMPs • Exposure based triggers work well • Good exposure models well respected based on best science – (though there is also a need to update - **opportunity**) • Tiered approach (but also an **opportunity** to do more)
Weaknesses	• Assessment of secondary poisoning (also an **opportunity**) • How to capture PEC_{soil} for pasture scenario • Need refinement of PEC_{soil} for VMPs • Exposure scenarios always very worst case/ highly conservative guard against false negatives overestimates risk linked to uncertainty • Many models not fit for current application • Monitoring data – its utility
Opportunities	• Physiologically based pharmacokinetic (PBPK/PBK) modelling • Regulatory harmonisation (EFSA. ECHA/ WFD/ REACH etc.) • Sharing best practice in model development • More effort in filling gaps in models for real scenarios e.g. sediment binding • Future models to manage mixtures • Fugacity modelling would enable refinement of models PEC/PNEC
Threats	• Conservatism in risk regulation • Misuse of pharmaceuticals e.g. vulture story in India can never be modelled or considered as part of risk analysis *cf.* off label use • Lack of ionic compounds consideration in existing models • Future innovations/ emerging drug discovery not catered for by models e.g. nano

Some questions and key issues were raised during the discussions, such as:

- How to harmonise regulatory risk modelling approaches?

It was stated that attempts should be made to harmonise the modelling requirements between EMA/EFSA/WFD/ECHA etc. - where practicable and useful - and ensure consistency in data provision/ interpretation and evaluation (e.g. PBTs, PECs, feeds, etc.). It was also recognised that some models like FOCUS work well for VMPs but could be nudged to have better utility. General maturity and currency of existing models should be improved.

- Tiered assessment

A generic concept across the field was that there is a huge potential to improve the tiered approach to better the ERA (inclusion of more quantitative elements at lower layers of the tiered approach to be considered).

- ERA models for pharmaceuticals

Ionic compounds and PBTs are difficult to model, reflecting a significant gap in knowledge. Inconsistency in data quality and availability is a challenge for exposure modelling. Entry to environment (point source vs diffuse) and key compartment identification are key considerations. It was noted that not all pharmaceuticals

are organic compounds, and thus there is uncertainty as to whether the most relevant models are being used for every case.

Future proofing models to respond to innovation in the industry (such as nano-delivery; innovative gene medicines) was discussed. A question was also discussed whether to address future scenarios e.g. climate change, water use or reuse, locality of populations has been raised. It was stated that no current models facilitate the understanding of environmental fate of pharmaceuticals in e.g. grey water irrigation systems, and there is a lack of robust environmental fate models for coastal settings (larger aggregations of human populations aligned to coastline regions).

- Improving product risk assessment

One weakness of the current regulatory framework is that the risk is based on the product, but it is the total burden of all similar products for the same indication that will drive the actual environmental risk. The industry should therefore extend the ERA modelling through access to sales or prescribing/consumption data to improve the environmental relevance.

There is also an opportunity to address mixtures and understand the interplay between different compounds. Exposure modelling could facilitate this interpretation but the question remains to what end – how can this information be used/considered?

- Utility of monitoring data

Are the right substances being monitored (selection is based around ease of determination, methodological developments)? Can we use models to mitigate needs to monitor/measure? How should the selection be based? Can we use monitoring to improve the models?

- Antibiotics and development of environmental antimicrobial resistance (AMR)

As a cause of concerns for human and veterinary health, is there any opportunity to model environmental drivers of AMR producing resistance?

3.1.4 Hazard P/B Assessment

The SWOT analysis of P/B assessment models is presented in Figure 7, below:

Figure 7: SWOT matrix of models used for P/B assessment

Strengths	• Understanding P/B behaviour of non-polar chemicals • Understanding aquatic organisms • Long-Range Transport • Regulatory acceptance of simple P/B assessment approach; right priorities identified • Models have generated a lot of process understanding, interpretation of experimental data and informing experimental design
Weaknesses	• Understanding air-breathing organisms • Ionogenic and highly hydrophobic chemicals usually outside applicability domain • k_m difficult to predict • Uncertainty analysis not reported, lack of uncertainty documentation – no tool available to do it correctly • Lack of appreciation of biological variability (especially relevant for Trophic Magnification Factor (TMF)) • Consideration of near-field environment (indoor/outdoor) • Lack of consideration of impact of other processes (e.g. bioturbation, biotransformation) on P • Lack of documentation of applicability domain of models used and use of tools outside of applicability domain • Poor reporting / lack of context for model results • Lack of support for phys/chem and fate property determination (while it underpins all calculations) • Lack of criteria consistency around the globe (different regulatory frameworks)
Opportunities	• Use of K_{oa} to describe air-breathing organisms • Use of K_m in B assessment • Influence of P and B data on T assessment • “one health” – integration HH and ENV modelling tools • Potential for use of data coming from industry • Use of REACH IUCLID dataset (ongoing?) • Development of best practices for model use • Connect P/B to exposure to incorporate multiple stressors / chemicals • Application of models in integration of new regulatory criteria
Threats	• Perception based on small amount of observations • Lack of regulatory regime flexibility makes use of new scientific approaches difficult • Type I and type II errors (too much precaution; overconfidence) • Simplistic use of model for data-poor substances • Lack of critical evaluation of models, overconfidence in results • Lack of understanding and acceptance of what models can provide

3.2 Day 2 Common themes and paths forward/key research needs

On the afternoon of Day 2, four common themes were distilled from the key questions and opportunities identified during the Day 1 SWOT analysis breakout sessions.

These four common themes were:

- Tiered assessment;
- Communication;
- Applicability Domain; and
- Decision tree on good practice.

A series of focused questions were identified for each theme and four syndicate sessions were then established, with each session was assigned one of the four identified themes. The syndicate groups were asked to further explore the theme and attempt to identify tangible paths forward, identify key research needs and address the potential for harmonisation across the sectors.

The syndicate sessions were established according to the following:

- Working group 1 (**moderator**: Diederik Schowanek, P&G and **rapporteur:** Mick Whelan, University of Leicester). Working group 1 addressed the Tiered assessment theme.
- Working group 2 (**moderator**: Matt MacLeod, Stockholm University and **rapporteur**: Jon Arnot, ARC). Working group 2 addressed the Communication theme.
- Working Group 3 (**moderator**: Dan Salvito, RIFM and **rapporteur**: Frank Gobas, SFU). Working group 3 addressed the Applicability domain theme
- Working Group 4 (**moderator**: Peter Fantke, DTU and **rapporteur**: Olivier Jolliet, University of Michigan) Working group 4 addressed the Decision tree on good practices theme.

Prior to the workshop, the participants had been allocated randomly into four groups (see Appendix A), and each group attended the above four syndicate sessions in turn, meaning that all participants discussed all of the four common themes.

In a final plenary session, the rapporteurs from each syndicate session reported on the discussions and identified paths forward/key research needs.

The identified questions for each theme (in blue), as well as a summary of the discussions/outputs (in green) are reported in the following sections.

3.2.1 Tiered Assessment

Moderator: Diederik Schowanek (P&G BIC, BE), Rapporteur: Mick Whelan (University of Leicester, UK)

Tiered Assessment process: Consensus is needed with respect to refining low tiers of assessment and role of conservative assumptions. What strategies could be initiated to address this?

Process needs to be fit for purpose, i.e. appropriate tool to answer the questions for a specific context (chemical type, far- vs near-field, environmental context, regulatory context (screening, prioritisation etc)).

Needs to be the possibility for flexibility within the tiered process, e.g. use of detailed/quantitative data at low tiers.

Decision tree preferable to linear tier, e.g. the same model could be used throughout the tiers but with higher levels of accuracy/quality of data at higher tiers.

Tiered risk assessment: Current risk assessment relies on external concentrations, although there is a movement towards characterising the concentration at the molecular initiating event. Consequently, there is an application for PBPK (Physiologically based pharmacokinetic modelling) and TK-TD (Toxicokinetic-toxicodynamic models) within an exposure pathway framework. Is this necessary at all tiers of evaluation?

Noted that total internal concentration in an organism is not helpful, as, for example, the chemical in the storage lipid may not be available.

Use of inverse modelling (using PBPK models to predict dose from toxic thresholds in *in vitro* assays) as is used for human toxicology could be applied to environmental toxicology.

Addressing uncertainty

Which input properties are critical to focus on with respect to uncertainty?

Use of sensitivity analysis as a tool to identify which input data to improve.

What is the acceptance of uncertainty in relation to different tiers of assessment, i.e. fit for purpose?

Likely more tolerance for uncertainty for lower tier models (uncertainty is compensated by assessment factors) or models used for screening/prioritisation

Use of percentile values for input values, and error bars, could be considered for higher tiers.

Mechanistic processes

How to achieve balance between complexity versus parsimony?

Which processes would benefit most from improved mechanistic insight?

Increasing quality of input data is key. This could be, for example, via use of mechanistic bioaccumulation model rather than regression model based on K_{ow}.

More complex models could give false impression of accuracy.

3.2.2 Communication

Moderator: Matt MacLeod (Stockholm University, SE), Rapporteur: Jon Arnot (ARC Arnot Research and Consulting, CA)

Recommendations for how to develop stakeholder groups.

Example of the FOCUS and SETAC groups in the agricultural chemical and vet med space

Example 2 could also be something analogous to AOP wiki where information regarding data and models are archived in a central location for broad use and application

The following recommendations were made:

1) Foster dialogue for tripartite involvement in:

   - Model development, i.e. applicability domains, purpose/objective, priority revisions

     e.g., prioritised revisions to EUSES by ECHA should include Member States and broader stakeholder community;

   - Platform for tiered exposure assessment. Perhaps EMIG (Exposure Modelling Interest Group) at SETAC, or ECETOC, could coordinate.

2) Implement a regular time-frame for review and updates of models (time-frame for revisions to current EUSES and guidance documents may be a few years).

3) Develop case studies for revisions to models (e.g. EUSES) to draw attention to viable alternative methods (e.g. consider public dissemination of case studies wherein decisions are based on evidence that does not conform to existing guidance and methods, to highlight possible revision to guidance, e.g. IATA (Integrated Approaches to Testing and Assessment))

4) Improve communication with the broader stakeholder community, including NGOs & public, to foster understanding (perhaps confidence) regarding how exposure models are used (and revised) to inform decision-making, and to increase transparency.

5) Improve communications to the broader stakeholder community on "what is risk?", and clarifying variability, and uncertainty in applicability domains, of bright-line thresholds in screening vs. deterministic assessments.

6) Improved peer-review: More initial involvement of multi-stakeholders and better coordination of reviewer teams that can comment on public policy documents and decisions. This could be coordinated by e.g. ECETOC or IPCP (International Panel on Chemical Pollution)

Is it possible to identify advantages and disadvantages with respect to harmonising across sectors?

- similarities and differences regarding drivers, both scientific and regulatory.

Concerns have been raised regarding divergence in how TGD is applied between biocides and general chemicals.

A centralised organisation framework of models and data for broad application in the exposure assessment could be developed, i.e., "on-line" wiki (flexible "live" inventory) or archive.

Improved methods for data sharing of industry data, such as sorption and degradation studies, could be developed.

3.2.3 Applicability Domain

Moderator: Dan Salvito (RIFM, USA), Rapporteur: Franck Gobas (Simon Fraser University, CA)

What could be the strategies for addressing Applicability Domain challenges? (e.g for chemicals: UVCBs, ionisable, nano, others).

The following strategies were recommended:

- Develop methods for extrapolation from one domain to another;
- Evaluate applicability domain of existing models for chemicals other than non-polar organics;
- Develop guidance for selecting physico-chemical properties for exposure modelling;
- Ensure that model evaluation includes a diversity of chemical and environmental characteristics, and identify sensitivities to chemical and environmental characteristics (e.g. temperature);
- Develop guidance (e.g. map) for the application domain (including spatial scale) of models;
- Develop case studies on how applicability domain can influence exposure modelling results;
- Develop a QPRF for exposure models (guidelines exist, but are not applied to all models).

What is the role of PBT assessment across the various sectors? There are for instance differences in perception between pharmaceutical products and general chemicals.

The following proposals were made in this context:

- Develop methods for determining physico-chemical property data for chemicals out of the applicability domain;
- Develop guidance for model users and developers on the use of physico-chemical property data for chemicals out of the applicability domain (Which chemical properties to use for substances not part of applicability domain?).

What could be the approaches for addressing mixtures, including the assessment of metabolites?

The following approaches were proposed:

- Provide guidance on the use of exposure models for chemical mixtures (including chemical applicability domain);
- Develop models (or use existing models) for chemical mixtures, including parent chemical and metabolites;
- Develop guidance on the required amount and quality of data relating to the nature of chemical mixtures, for conducting exposure modelling.

What is the role of monitoring data within exposure models? For instance, is exposure modelling keeping pace with advances in analytical developments, such as the growth in liquid chromatography - mass spectroscopy (LC-MS) capability and non-target analysis?

The following recommendations were made in this context:

- Integrate approaches for monitoring and modelling studies (models currently do not take full advantage (e.g. in their refinement) of results from monitoring studies, and modelling data can be used to identify candidates for monitoring programs);
- Develop guidance on the use of monitoring data to test/develop exposure models (including guidance on the collection of non-target ecological data (e.g. organic carbon, stable isotope data for TMF studies);
- Use 'Big Data' (e.g. sales, marketing data) to derive exposure estimates as input for exposure models;
- Develop guidance for Quality Assurance and control of food-web monitoring data (e.g. for the development of TMF);
- Explore use of NORMAN data sharing network;

How could the non-chemical stressors in exposure models be considered e.g. antibiotics and AMR concern (for human and ecological health) and climate change (impact on temperature, pH, precipitation)?

The following recommendation was made in this context:

- Develop methodology to determine greatest vulnerabilities of systems (e.g. smokers vs. non-smokers) for the purpose of hazard/exposure model.

3.2.4 Towards a decision tree for exposure modelling

Moderator: Peter Fantke (Technical University of Denmark, DK), Rapporteur: Olivier Jolliet (University of Michigan, School of Public Health, USA)

Context: Improve the quality and use of exposure models and data in regulations
Aim of process tree: Select an appropriate model, facilitate its use and communicate properly

I. What are the general aims for good exposure modelling practices?

- Model must be fit for purpose (valid/applicable/feasible) for the specific decision context and mechanistically/scientifically sound
- Must address all relevant stressors, exposure pathways and receptors
- Parsimony: Model requires as little work/input data as possible
- Results must be communicated along with their level of accuracy and confidence that results are representative for the addressed question (based on uncertainty/variability/quality of input data).

II. a) Problem formulation: define the decision context and needs

The following should be defined for problem formulation:

- The decision you want to make/question you want to answer
- The required spatial and temporal scale
- The level of confidence, accuracy and precision needed
- Whether one-sided (conservative) or two-sided (compare two outputs) confidence is required.

II. b) Key questions and criteria to consider

Scoping

- All potential sources/stressors and their respective relevance
- Main chemicals involved and their characteristics (e.g. ionisable)

- Other stressors/interactions that may make receptors more vulnerable
- Environmental compartments that are relevant
- Mode of entry into the environment/system
- Continuous, intermittent or pulse source
- Exposure pathway (as far as known - iterative process)
- Relevant receptors/key species
- Temporal / spatial scale

Model selection/design

- Prepare matrix of available models at the different tiers and their main characteristics (use of model factsheets could be considered)
- Origin of the model / data required – provided / coverage for substance classes / geographical coverage / level of resolution / model documentation / outputs / system requirements / input & output interface – batch processing / for which tier is the model suited - Tier 0 to 3
- Level of acceptance of the model (at lower tier, use a model that is well accepted; at higher tier, may select more specialised/complex model)
- Main factors driving the results/Input data requiring good accuracy
- Main pathways/stressors covered by the model.

The following was proposed as a potential Model Selection Matrix to use:

Decision criteria	Models Model A	Model B	Model C	Model D	← 1 fact sheet per model
Coverage					
Releant sources and stressors					
Relevant compartments					
Mode of entry					
Relevant exposure pathways					
Most influential factors					
Relevant receptors					
Boundaries					
Spatiotemporal scale					
Geographical coverage					
Data					
Availability					
Quality (sources, emissions, physchem properties)					

Input data availability and quality

- Emission estimates: What are the available data and can defaults be used?
- What is the quality of the emission data? If not sufficient, stress to decision maker the need for refinement.
- Is it possible to perform reverse modelling to determine emission data?

Chemical properties

- What are the key chemical properties that need to be accurate?
- What is the level of accuracy of these key properties and factors?

Evaluation and domain of applicability

- Check the domain of applicability / chemical.
- What is the weakest point in the model for the considered context?
- Uncertainties in emission factors.
- What are the main causes for variability and what is their relevance?
- What are the key assumptions in the models?
- If several models give different answers – provide guidance on how to deal with this issue.
- What monitoring data are available for evaluation purposes?

4. IT MODELLING FAIR

At the end of Day 1, the workshop programme included a slot for an 'IT Modelling Fair' where some of the participants were invited to give demonstrations of specific exposure modelling tools and to offer attendees some hands-on experience.

The format for the IT Fair was the formation of clusters at different corners of the various meeting rooms available and each tool was demonstrated with the support of a projector and screen, or poster.

The tools presented during the fair are listed below, and described in the succeeding sections:

- iSTREEM model
- MERLIN-Expo
- UFZ LSERdatabase
- PiF Model: Coupled near-field and far-field exposure assessment framework for chemicals in consumer products
- RAIDAR Risk Assessment IDentification And Ranking
- GREAT-ER 4.0: Geo-referenced Regional Exposure Assessment Tool for European Rivers
- Spatially Distributed Leaching Modelling of Agrochemicals

Two posters were also displayed:

- PBK models and VCBA: Automated workflows for modelling chemical fate, kinetics, and toxicity
- EU platform IPCHEM: the reference platform chemical monitoring data in Europe.

4.1 iSTREEM Model

Presenter: Chris Holmes (Waterborne Environmental, Inc., USA)

iSTREEM® is a web-based model which estimates spatially-explicit environmental concentrations of down-the-drain chemicals in effluent and receiving waters across the USA. Water column concentrations are estimated at the discharge points of over 10,000 municipal wastewater treatment plants (WWTPs) and downstream receiving waters covering more than 350,000 km of rivers. The model incorporates WWTP information on population served, treatment type, and facility flow which are linked to a hydrologic framework providing flow and connectivity between facilities and downstream sites. As part of the hydrologic routing, a first-order decay is implemented to simulate environmental processes that remove chemical from the water column. The model allows for regional use rates to better simulate potential geographic variability in emissions, as well as differing removal rates to account for different facility treatment types. The model is implemented in a map-enabled website (www.iSTREEM.org) which requires no local software installation. Model runs are defined by the user and performed on the iSTREEM server, and available for visualisation and download of model results when completed.

4.2 MERLIN-Expo

Presenters: Frederik Verdonck (Arche Consulting, BE) and Philippe Ciffroy (EDF, FR)

MERLIN-Expo tool contains a set of models for simulating the fate of chemicals in the main environmental systems (multimedia model) and in the human body (PBPK model). It features powerful numerical solvers in combination with state of the art methods for uncertainty and sensitivity analysis. More info can be found on the website (http://merlin-expo.eu)

4.3 UFZ LSERdatabase

Presenter: Kai-Uwe Goss (Helmholtz Centre for Environmental Research UFZ, DE)

Database to derive equilibrium partition coefficients for organic neutral chemicals in hundreds of different partition systems.

http://www.ufz.de/index.php?en=31698&contentonly=1&m=0&lserd_data[mvc]=Public/start

4.4 PiF Model: Coupled near-field and far-field exposure assessment framework for chemicals in consumer products

Presenters: Peter Fantke (Technical University of Denmark, DE) and Olivier Jolliet (University of Michigan, School of Public Health, USA)

To meet the increasing need for assessing exposure to chemicals in consumer products for life cycle assessment (LCA), chemical alternatives assessment (CAA), and high throughput risk-based screening (HTS), we present a mass-balance based framework to assess multi-pathway human exposure to chemicals in consumer products that can be integrated with health effects modelling based on comparative and quantitative metrics. The matrix-based framework considers multiple transfers between near-field and far-field environmental compartments. We will illustrate the functionality of the framework along an example of personal care products and show that it is aligned in its approach with the UNEP/SETAC scientific consensus model USEtox for characterising human toxicity and ecotoxicity impacts. We will conclude with a brief demonstration of how this framework fills-in important gaps in current assessments and how it can be used in various science-policy fields, including the prioritisation and ranking of chemicals, chemical substitution and life cycle toxicity characterisation.

4.5 RAIDAR: Risk Assessment IDentification And Ranking

Presenter: Jon Arnot (ARC Arnot Research and Consulting, CA)

RAIDAR combines multimedia mass balance environmental fate and bioaccumulation models to quantify chemical transport and exposures from diffuse emission sources to representative ecological receptors and

humans in an evaluative regional-scale environment[16,17]. Representative plant, invertebrate and vertebrate species including fish, wildlife, agricultural crops and livestock are included. Primary producers and invertebrates bioconcentrate chemical from their ambient environment of air, water, soil, or sediment. One-compartment toxicokinetic models are used for vertebrate species to simulate bioconcentration, biomagnification, absorption, elimination and biotransformation processes. Dietary preferences are indicative of general trophic interactions. Toxicity data can be included (e.g., critical body residues) for risk estimation and comparative risk assessments. The model provides output in terms of chemical concentrations, fugacities and activities. The model is available for free download at www.arnotresearch.com. The model has recently been revised to better address key processes for the fate and bioaccumulation of ionisable organic chemicals (IOCs) recognising the limitations of chemical property information for IOCs to parameterise and use the models[18].

Summary Presentation:

- Overview of the new model (coded in Excel/VBA);
- Summary of Input Parameter requirements and Primary Output (exposure assessment factors, risk assessment factors, uncertainty analysis);
- Case study application demonstrating parameterisation and application of the models for neutral and organic chemicals, highlighting the tiered approach for model parameterisation as determined by chemical property data availability.

4.6 GREAT-ER 4.0: Geo-referenced Regional Exposure Assessment Tool for European Rivers

Presenter: Michael Matthies (University of Osnabrück, DE)

Nils Kehrein*, Jörg Klasmeier, Jürgen Berlekamp, Michael Matthies
Institute of Environmental Systems Research, University of Osnabrück
Barbarastr. 12, D-49076 Osnabrück, Germany

The geo-referenced regional exposure assessment tool for European rivers (GREAT-ER) was developed for the prediction of spatially explicit exposure concentrations of typical down-the-drain chemicals in whole river basins [19]. New features for scenario creation and analyses were amended for use in river basin management or within the European Water Framework Directive implementation process[20]. Improvements of the new

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* Current address: Dr. Knoell Consult GmbH, Marie-Curie-Straße 8, 51377 Leverkusen, Germany
[19] Feijtel, T.C.J., Boeije, G., Matthies, M., Young, A., Morris, G., Gandolfi, C., Hansen, B., Fox, K., Holt, M., Koch, V., Schröder, R., Cassani, G., Schowanek, D., Rosenblom, J., Niessen, H., 1997. Development of a geography-referenced regional exposure assessment tool for european rivers - GREAT-ER. Chemosphere 34, 2351-2374.

[20] Kehrein, N., Berlekamp, J., Klasmeier, J. 2015. Modeling the fate of down-the-drain chemicals in whole watersheds: New version of the GREAT-ER software. Environmental Modelling & Software 64,1-8.

model version GREAT-ER 4.0 are exemplary illustrated by means of an extensive case study for the pharmaceutical diclofenac in the German watershed of Ruhr River, a tributary of River Rhine. Comparison with monitoring data corroborates the capability of the probabilistic model to realistically predict spatial surface water concentration ranges for non-persistent chemicals. Based on the evaluation of the actual contamination, two management scenarios are investigated in terms of their reduction potential. The analysis demonstrates how the model allows for *a priori* evaluation of mitigation strategies.

4.7 Spatially Distributed Leaching Modelling of Agrochemicals

Presenter: Nils Kehrein (Knoell Consult, DE)

A GIS assisted system was developed to ease the application of higher tier approaches within the European groundwater risk assessment of pesticides.

It incorporates publicly available datasets and the model PEARL to assess the variability of predicted leaching concentrations. It enables the creation of groundwater vulnerability assessments, selection of representative scenarios, and supports the interpretation of monitoring data.

4.8 PBK models & VCBA (Poster): Automated workflows for modelling chemical fate, kinetics, and toxicity

Presenter: Alicia Paini (European Commission: DG JRC, IT)

Automated workflows for human exposure (mainly PBK models) and *in vitro* exposure (Virtual Cell Based Assay) that were developed within the EU/CosEU SEURAT1 research initiative (COSMOS cluster).

4.9 EU Platform IPCHEM (Poster): The reference platform for chemical monitoring data in Europe

Presenter: Alicia Paini (European Commission: DG JRC, IT)

The Information Platform for Chemical Monitoring https://ec.europa.eu/jrc/en/event/conference/ipchem

5. CLOSE OF THE WORKSHOP

The organising committee thanked everyone for their participation to this interesting workshop and agreed to further scope activity and/or research in the identified areas. The activity/research identified will then be presented to, and evaluated by, the ECETOC Scientific Committee and the Cefic LRI Strategic Implementation Group.

Todd Gouin reiterated the thanks given at the end of Day 1 to:

- **ECETOC**, for providing the opportunity to bring us together
- **Speakers**, for providing their time in helping stimulate and position workgroup discussions
- **Moderators/Rapporteurs**, for providing the all-important role of guiding and reporting back on breakout discussions
- **Lena Esteves**, for providing all the logistical support to help things run smoothly
- **Workshop participants**, for their input over the two days which was key to ensuring that the workshop output was successful and impactful.

6. RECOMMENDATIONS AND NEXT STEPS

The presentations, syndicate sessions and plenary discussions comprising the 2-day workshop indicated general consensus from workshop participants on the following principles of good modelling practice and application to decision making:

1. A decision process must start with problem definition, followed by further scoping (prompted by specific questions regarding temporal/spatial scale, relevant compartments/receptors etc.), considerations of input data availability and, finally, model selection. Exposure models need to be fit for purpose, i.e. an appropriate tool to answer questions for a specific context.

2. Tiered assessments are key to ensuring models are fit for purpose. The most effective way of actualising tiered assessment is via a decision tree.

3. Guidance regarding applicability domain considerations is essential for good use of models. This should be provided alongside advice for/development of models for chemicals outside the applicability domain, e.g. ionics, hydrophobics etc.

4. Improving the quality of input data is key for reducing uncertainty in exposure modelling. Sensitivity analysis can be used as a tool to identify which input data is critical with respect to uncertainty.

5. Modelling results must be communicated along with the associated level of uncertainty/confidence. Higher levels of uncertainty may be acceptable at lower tiers, or where results are used for screening purposes.

6. Loss of parsimony in exposure modelling is a potential threat to acceptance of models and credibility in risk assessment.

7. Advice and model development for addressing chemical mixtures is needed. Non-chemical stressors in the environment is an important consideration in this regard.

8. Use of monitoring data, and research campaign data (e.g. sales or prescription/consumption data), for model design and refinement, and visa-versa, are areas that could be better exploited.

The workshop identified the following recommendations:

I. Develop sector-specific decision trees and heuristic techniques to promote fit-for-purpose modelling.

II. Foster improved communication and coordination of the science underlying models used across the different industry sectors. This is important to ensure best current practice and future development of the science of exposure assessment.

III. Encourage involvement of and communication with all stakeholders (e.g. regulators, industry, NGOs, public) in model updates (***e.g. potential upcoming EUSES update***) and developments. Platforms for such activity could be established **via e.g. the SETAC EMIG, OECD groups, ECETOC**.

The workshop Organising Committee will consider how recommendations I-III above could be taken forward within ECETOC, e.g. via a dedicated Task Force or Expert Working Group.

The workshop Organising Committee will also investigate the feasibility of points 7 and 8 above being taken forward in the form of a research project (e.g. via Cefic LRI). The NORMAN Network is a potential important stakeholder in such a research project.

All participants to the workshop were made aware of the Royal Society of Chemistry Journal special issue 'Environmental Science: Processes and Impacts (ESPI)', to be published early January 2018. Several workshop participants have subsequently made submissions to this special issue. At the time of publication of this workshop report, the special issue is already published (Environ Sci: Processes Impacts, 2018,20, rsc.li/modeling).

ABBREVIATIONS

AMR	Antimicrobial resistance
AOP	Adverse outcome pathway
B	Bioaccumulative
CAA	Chemical alternatives assessment
CHARM	Complex Hazardous Air Release Model
CHESAR	CHEmical Safety Assessment and Reporting tool
DSL	Domestic substances list
DTU	Technical University of Denmark
EC	European Commission
ECCC	Environment and Climate Change Canada
ECETOC TRA	ECETOC Targeted Risk Assessment (TRA) tool
ECHA	European Chemicals Agency, Helsinki, Finland
EFSA	European Food Safety Authority
EMA	European Medicines Agency
ENV	Environment
ERA	Environmental risk assessment
ERC	Environmental release category
ESD	Emission scenario documents
ESPI	Environmental science: processes and impacts
EU	European Union
EUSES	European unified system for the evaluation of substances
FOCUS	Forum for Co-ordination of pesticide fate models and their Use
GIS	Graphic information system
GREAT-ER	Geographically-referenced regional exposure assessment tool for European rivers
HH	Human health
HMP	Human medicinal products
IOCs	Ionisable organic chemicals
IPCHEM	Information Platform for Chemical Monitoring
IPCP	International Panel on Chemical Pollution
i-STREEM®	in-stream exposure model
K_m	Body biotransformation rate
K_{oa}	Octanol-air partition coefficient
K_{ow}	Octanol-water partition coefficient
LCA	Life cycle assessment
LC-MS	Liquid chromatography - mass spectrometry
LRTP	Long-range transport potential
LSER	Linear solvation energy relationship
MERLIN-Expo	Modelling Exposure to chemicals for Risk assessment: a comprehensive Library of multimedia and PBPK models for Integration, Prediction, uNcertainty and Sensitivity analysis
NAS	National Academies of Science

NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
P	Persistent
PEARL	Pesticide Emission At Regional and Local Scales
Pangea	A local to global, spatial multi-scale, multimedia environmental fate and transport, and multi-pathways population exposure framework for modelling chemical substances
PBK	Physiologically based kinetic
PBT	Persistent, bioaccumulative, toxic
PBPK	Physiologically-based pharmacokinetic
PEC	Predicted environmental concentration
PetroRisk	A spreadsheet tool, developed by Hydroqual for Concawe, that performs environmental risk assessments for petroleum substances using principles provided by the European Chemical Agency (ECHA) for fulfilling stakeholder obligations under the EU REACH regulation
PiF Model	Coupled near-field and far-field exposure assessment framework for chemicals in consumer products
PNEC	Predicted no effect concentration
POP	Persistent organic pollutant
Pov	Overall persistence
PPP	Plant protection products
RAIDAR	Risk Assessment IDentification And Ranking
REACH	Registration, evaluation, authorisation and restriction of chemicals
SETAC	Society of Environmental Toxicology and Chemistry
SETAC EMIG	SETAC Exposure Modelling Interest Group
SPERCs	Specific environmental release categories
STP	Sewage treatment plant
SWOT	Strengths, weaknesses, opportunities and threats
TGD	Technical guidance document
TK-TD	Toxicokinetic and toxicodynamic
TMF	Trophic magnification factor
TRS	Temporal remote state
UFZ	Helmholtz Centre for Environmental Research
UNEP	United Nations Environment Programme
USEtox	A scientific consensus model endorsed by the UNEP/SETAC Life Cycle Initiative for characterising human and ecotoxicological impacts of chemicals
UVCB(s)	Substance(s) of unknown or variable composition, complex reaction products or biological materials
VCBA	Virtual cell based assay
VMP	Veterinary medicinal products
WFD	Water Framework Directive
WWTP	Waste water treatment plant

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APPENDIX A: WORKSHOP PROGRAMME

PROGRAMME DAY 1: THURSDAY 4 MAY 2017

08:00 – 08:30	**Registration and Welcome Coffee (La Rotonde)**	
08:30 - 08:50	**Welcome and introductory remarks** **ECETOC**	**Alan Poole**
08:50 - 09:20	**Multimedia Fate and Exposure Models: Origins, Evolution, and Future Prospects** **University of California, Berkeley**	**Tom McKone**
09:20 - 09:40	**Development towards regulatory tools** **Environment and Climate Change Canada**	**Mark Bonnell**
09:40 - 10:00	**Pesticide modelling within regulatory context** **BASF**	**Krisztian Szegedi**
10:00 - 10:20	**Pharma and use of exposure/fate models** **Astra-Zeneca**	**Jason Snape**
10:20 - 11:00	**Coffee break (La Rotonde)**	
11:00 - 11:15	**Environmental Exposure Assessment under REACH and Biocides** **ECHA**	**Stefano Frattini**
11:15 - 11:30	**The role of fate/exposure models within P & B assessment** **ETH Zürich & Masaryk University**	**Martin Scheringer**

PROGRAMME DAY 1: THURSDAY 4 MAY 2017

11:30 – 12:30	**Four Syndicate Sessions (SWOT analysis)**	
Workgroup 1	**General Chemicals/Biocides (Thalys 2)**	
	Moderator: **Johannes Tolls** (Henkel)	*Rapporteur*: **Graham Whale** (Shell)
Workgroup 2	**Agrochemicals (Thalys 3)**	
	Moderator: **Melanie Kah** (Univ. Vienna)	*Rapporteur*: **Krisztian Szedgedi** (BASF)
Workgroup 3	**Pharmaceuticals (Thalys 4)**	
	Moderator: **Jason Snape** (Astra-Zeneca)	*Rapporteur*: **Jason Weeks** (Independent)
Workgroup 4	**Hazard P/B Assessment (Thalys 1)**	
	Moderator: **Martin Scheringer** (ETH Zürich & Masaryk University)	*Rapporteur*: **Miriam Leon Paumen** (ExxonMobil)

12:30 - 13:30	**Lunch (La Rotonde)**

13:30 – 15:30	**Four Syndicate Sessions (SWOT analysis continued)**	
Workgroup 1	General Chemicals/Biocides (Thalys 2)	
	Moderator: **Johannes Tolls** *(Henkel)*	*Rapporteur:* **Graham Whale** *(Shell)*
Workgroup 2	**Agrochemicals (Thalys 3)**	
	Moderator: **Melanie Kah** *(Univ. Vienna)*	*Rapporteur:* **Krisztian Szedgedi** *(BASF)*
Workgroup 3	**Pharmaceuticals (Thalys 4)**	
	Moderator: **Jason Snape** (Astra-Zeneca)	*Rapporteur*: **Jason Weeks** (Independent)
Workgroup 4	**Hazard P/B Assessment (Thalys 1)**	
	Moderator: **Martin Scheringer** (ETH Zürich & Masaryk University)	*Rapporteur:* **Miriam Leon Paumen** (ExxonMobil)

15:30 - 16:00	**Coffee break (La Rotonde)**

PROGRAMME DAY 1: THURSDAY 4 MAY 2017

		Chair: Diederik Schowanek
16:00 - 16:45	**IT Modelling Fair (short Introductions – 5 min. each)**	
	iSTREEM Model (Thalys 1)	**Chris Holmes**
	MERLIN-Expo (Thalys 2)	**Frederik Verdonck**
	UFZ LSERdatabase (Thalys 3)	**Kai-Uwe Goss**
	PiF Model (Thalys 4)	**Peter Fantke/Olivier Jolliet**
	RAIDAR (Expo)	**Jon Arnot**
	GREAT-ER 4.0 (Expo)	**Michael Matthies**
	Spatially Distributed Leaching Modelling of Agrochemicals (Expo)	**Nils Kehrein**
	Poster: PBK models VCBA (Expo)	**Alicia Paini**
	Poster: EU Platform IPCHEM (Expo)	**Alicia Paini**
16:45 – 18:00	**IT Modelling Fair Displays**	

Close of first day

19:30	**Dinner: Cospaia Restaurant**

PROGRAMME DAY 2: FRIDAY 5 MAY 2017

08:00 - 08:30	**Welcome *Coffee break* (La Rotonde)**	
08:30 - 09:30	**Plenary** Breakouts report back (5-10 minutes each) Identify key points, consensus and set the scene for day 2	**Chair: Todd Gouin**
9:30 - 10.00	**Coffee break (La Rotonde)**	
10:00 - 10:30	**Recognising the important role of exposure models in characterising risk in the 21st Century**	**Jon Arnot** **ARC Arnot Research and Consulting**
10:30 - 11:00	**Thoughts from Europe – Roskilde workshop**	**Henriette Selck** **Roskilde University**
11:00 - 11:30	**Strategies to provide human biomonitoring trend data for exposure modelling**	**Jochen Mueller** **The University of Queensland**
11:30 - 12:00	**Planetary boundary threats from chemical pollution**	**Matthew MacLeod** **Stockholm University**
12:45 - 13:45	**Lunch (La Rotonde)**	

13:45 – 16:15 Four Syndicate sessions (SWOT analysis should have identified weaknesses and opportunities, good for this session to split groups up from first day to further explore, and attempt to identify possible tangible paths forward, particular interest in identifying cross-sector opportunities)

Working Group 1 a: Tiered Assessment

Moderator: **Diederik Schowanek** *Rapporteur*: **Mick Whelan**

Working Group 2 b: Communication

Moderator: **Matt MacLeod** *Rapporteur*: **Jon Arnot**

Working Group 3	**c: Applicability Domain**	
	Moderator: **Dan Salvito**	*Rapporteur*: **Frank Gobas**
Working Group 4	**d: Towards a decision tree on good practices for exposure modelling**	
	Moderator: **Peter Fantke**	*Rapporteur*: **Olivier Jolliet**

16:15 - 16:30	***Coffee break* (La Rotonde)**	

16:30 - 17:45	**Plenary: feedback & discussion**	**Chair: Todd Gouin**
	Breakouts report back (5-10 minutes each)	
	Identify key points, consensus and research needs	

17:45	**End of workshop**

Close of Workshop

DAY 1

SYNDICATE SESSION 1: GENERAL CHEMICALS/BIOCIDES

First Name	Name
Johannes	**Tolls (*Moderator*)**
Graham	**Whale (*Rapporteur)***
Knut	Breivik
Louise	Camenzuli
Stefano	Frattini
Kai-Uwe	Goss
Olivier	Jolliet
Paul	Mason
Drew	McAvoy
Nienke	Müller
Jan	Oltmanns
Dan	Salvito
Diederik	Schowanek
Frederik	Verdonck
Christopher	Warren
Mick	Whelan

SYNDICATE SESSION 2: AGROCHEMICALS

First Name	Name
Melanie	**Kah (*Moderator*)**
Krisztian	**Szegedi (*Rapporteur)***
Phil	Branford
Antonio	Di Guardo
Peter	Fantke
Chris	Holmes
Nils	Kehrein
Thomas	McKone
Stefan	Reichenberger
Gerald	Reinken
Andy	Sweetman
Nathalie	Vallotton

DAY 1

SYNDICATE SESSION 3: PHARMACEUTICALS

First Name	Name
Jason	**Snape (*Moderator*)**
Jason	**Weeks (*Rapporteur)***
Jon	Arnot
Bryan	Brooks
Alice	Brousse
Philippe	Ciffroy
Darci	Ferrer
Jochen	Mueller
Alicia	Paini
Karina	Petersen
Chris	van den Eede
Lucy	Wilmot
Richard	Williams

SYNDICATE SESSION 4: HAZARD P/B ASSESSMENT

First Name	Name
Martin	**Scheringer (*Moderator*)**
Miriam	**Leon Paumen (*Rapporteur)***
James	Armitage
Sami	Belkhiria
Mark	Bonnell
Katrine	Borgå
Susan	Csiszar
Miriam	Diamond
Peter	Fisk
Frank	Gobas
Sylvia	Jacobi
Qiang	Li
Matt	MacLeod
Michael	Matthies
Henriette	Selck

DAY 2

SYNDICATE SESSION 1: A	
First Name	**Name**
Diederik	**Schowanek (*Moderator*)**
Mick	**Whelan (*Rapporteur)***
Katrine	Borgå
Phil	Branford
Bryan	Brooks
Peter	Fisk
Melanie	Kah
Nils	Kehrein
Paul	Mason
Gerald	Reinken
Jason	Snape
Johannes	Tolls
Christopher	Warren
Richard	Williams

SYNDICATE SESSION 2: B	
First Name	**Name**
Matt	**Macleod (*Moderator*)**
Jon	**Arnot (*Rapporteur)***
Knut	Breivik
Miriam	Diamond
Stefano	Frattini
Sylvia	Jacobi
Karina	Petersen
Andy	Sweetman
Nathalie	Vallotton
Chris	van den Eede
Frederik	Verdonck
Jason	Weeks
Graham	Whale

DAY 2

SYNDICATE SESSION 3: C	
First Name	**Name**
Dan	**Salvito (*Moderator*)**
Frank	**Gobas (*Rapporteur)***
Alice	Brousse
Louise	Camenzuli
Philippe	Ciffroy
Susan	Csiszar
Kai-Uwe	Goss
Miriam	Leon Paumen
Michael	Matthies
Thomas	McKone
Jochen	Mueller
Jan	Oltmanns
Alicia	Paini
Stefan	Reichenberger
Henriette	Selck

SYNDICATE SESSION 4: D	
First Name	**Name**
Peter	**Fantke (*Moderator*)**
Olivier	**Joillet (*Rapporteur)***
James	Armitage
Sami	Belkhiria
Mark	Bonnell
Antonio	Di Guardo
Darci	Ferrer
Chris	Holmes
Qiang	Li
Drew	McAvoy
Nienke	Müller
Martin	Scheringer
Krisztian	Szegedi
Lucy	Wilmot

APPENDIX B: WORKSHOP PARTICIPANTS

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Jon	Arnot	ARC Arnot Research and Consulting, CA
Sami	Belkhiria	Dow Performance Silicones - Europe, BE
Mark	Bonnell	Environment and Climate Change Canada,CA
Katrine	Borgå	University of Oslo, NO
Phil	Branford	TSGE Consulting Limited, UK
Knut	Breivik	NILU - Norwegian Institute for Air Research, NO
Bryan	Brooks	Baylor University, USA
Alice	Brousse	ECETOC, BE
Louise	Camenzuli	ExxonMobil Petroleum & Chemicals BVBA, BE
Philippe	Ciffroy	EDF R&D, FR
Susan	Csiszar	P&G, USA
Antonio	Di Guardo	University of Insubria, IT
Miriam	Diamond	University of Toronto, CA
Lena	Esteves	G. Verde Communications/ ECETOC, BE
Peter	Fantke	Technical University of Denmark (DTU), DK
Darci	Ferrer	American Cleaning Institute, USA
Peter	Fisk	Peter Fisk Associates, UK
Stefano	Frattini	ECHA, Finland, FI
Frank	Gobas	Simon Fraser University, CA
Kai-Uwe	Goss	Helmholtz Centre for Environmental Research UFZ, DE
Todd	Gouin	Unilever, UK
Chris	Holmes	Waterborne Environmental, Inc., USA
Sylvia	Jacobi	Albemarle Europe SPRL, BE
Olivier	Jolliet	University of Michigan, School of Public Health, Environmental Health Sciences, USA
Melanie	Kah	University of Vienna, AT
Nils	Kehrein	Knoell Consult, DE
Miriam	Leon Paumen	ExxonMobil, BE
Qiang	Li	Clariant Produkte GmbH, DE
Matt	MacLeod	Stockholm University, SE

Name	Affiliation	E-mail
Paul	Mason	SC Johnson, UK
Michael	Matthies	University of Osnabrück, DE
Drew	McAvoy	University of Cincinnati, USA
Thomas	McKone	University of California, Berkeley, USA
Jochen	Mueller	The University of Queensland, AU
Nienke	Müller	Technical University of Denmark, DK
Jan	Oltmanns	FoBiG Consultancy, DE
Alicia	Paini	European Commission DG JRC, IT
Karina	Petersen	Norwegian Institute for Water Research, NIVA, NO
Alan	Poole	ECETOC, BE
Stefan	Reichenberger	Dr. Knoell Consult GmbH, DE
Gerald	Reinken	Bayer AG, Crop Science, DE
Dan	Salvito	RIFM, USA
Martin	Scheringer	ETH Zürich and Masaryk University, Brno, CH/CZ
Diederik	Schowanek	Procter & Gamble BIC, BE
Henriette	Selck	Roskilde University, DK
Jason	Snape	Astra-Zeneca, UK
Andy	Sweetman	Lancaster University, UK
Krisztian	Szegedi	BASF, SE
Johannes	Tolls	Henkel, DE
Nathalie	Vallotton	Dow Europe GmbH, CH
Chris	van den Eede	Zoetis, USA
Frederik	Verdonck	ARCHE, BE
Christopher	Warren	ExxonMobil, QA
Jason	Weeks	Independent, UK
Graham	Whale	Shell, UK
Mick	Whelan	University of Leicester, UK
Richard	Williams	Centre for Ecology & Hydrology, UK
Lucy	Wilmot	ECETOC, BE

APPENDIX C: ORGANISING COMMITTEE

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