EPA ExpoCast Exposure-Based Prioritization

Expert Elicitation Working Group

Read Ahead Material for Survey

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I. Overview

Hundreds of new chemical compounds are introduced every year, but little is known about the risks associated with the life cycles of these compounds, especially when it comes to exposure. To better prioritize further exposure and toxicity research in a data-poor environment, the EPA requires a parsimonious, high-throughput method to characterize and screen these emerging chemicals based on exposure potential.

EPA's Office of Research and Development launched the ExpoCast program to advance development of novel methodologies for evaluating chemicals based on their biologically relevant potential for human exposure. Combined with toxicity information from ToxCast, a complementary program, the EPA will be able to screen and prioritize chemicals based on cutting-edge experimental and computational methodologies.

An "Exposure Challenge" was organized, challenging several scientists to develop their own exposure-based prioritization methods on a small set of well-characterized chemicals (see Appendix B for the test chemicals). In addition, as a high level, initial screening tool, a team from US Army Engineer Research & Development Center (ERDC) was asked to develop a prioritization tool using methods from the field of Decision Analysis, drawing upon the various parameters used in the other Exposure Challenge models. This decision model framework has been developed (more details on the decision model are contained in Appendix A), and the next step is to elicit criteria weights from subject matter experts.

Overview of the Ongoing Effort

This effort is structured as a two-phase project, including a modeling phase (Phase 1) and an elicitation phase (Phase 2). Phase 1 has been completed.

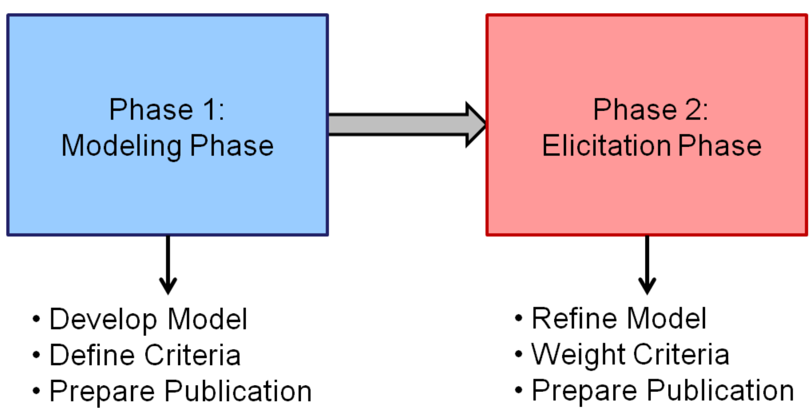

Figure 1 Schematic of prioritization effort

The following summary provides a road map of what has already accomplished (identified by check marks) and what still remains to be done (identified by bullet points):

Phase 1:

- ✓ Identify criteria and sub-criteria for exposure-based assessment
- ✓ Develop proof-of-concept decision model
- ✓ Collect data for case study chemicals
- ✓ Generate case study & conduct sensitivity analysis
- ✓ Prepare white paper on the potential use of Value of Information (VoI) analysis
- ✓ Present preliminary results at Exposure Workshop (Sept. 2011) and Society for Risk Analysis (Dec. 2011) conferences
- ✓ Prepare publication for *PLOS ONE* (Mitchell et al., 2013)

Phase 2:

- ✓ Refine model
- Conduct individual surveys with experts to elicit criteria weights
- Prepare second publication
- Explore integration with existing ToxCast models and tools

Summary of the Expert Elicitation Process

The goal of this phase is to integrate the domain-specific knowledge and judgment of subject matter experts into the existing prioritization framework. Currently, the following elements are included:

- a goal (prioritize chemicals based on exposure potential),
- alternatives (the chemicals being assessed),
- criteria (the measures by which each chemical can be assessed for exposure potential), and
- scores (the actual values that each chemical exhibits across each of the relevant criteria, collected from literature and other models).

However, the relative importance of the criteria and sub-criteria to one another is yet to be determined. The purpose of this expert elicitation is to determine the ranking and valuation of the criteria, to be utilized by the model as criteria "weights". These weights will then be integrated into the model.

II. Stakeholder Survey Process Overview

Survey Objectives

You will be asked to rank and evaluate the criteria and sub-criteria that have been developed by the ERDC team after feedback from Phase 1 of the model. From your responses, quantitative weights will be generated that will determine the relative importance of the different criteria and sub-criteria in the exposure model.

These weights are intended to reflect the best judgment of the expert community, representing industry, government and academia, in order to create an exposure-based prioritization model for chemicals. The results of model will be used to prioritize chemicals for further data gathering and toxicological analysis.

What Participants Can Expect

First, you will be asked to rank the two main criteria in order of their importance to exposure potential. Next, you will be asked to determine the importance of each criterion relative to one another. You will do this by assigning an importance score of 100 to the top ranked criterion, and providing an importance score of less than 100 to the other criterion. The difference in score reflects the difference in relative importance between the top criterion and the criterion in question. This is done on a scale from 0 to 100, so scores that are very close (e.g. 99 and 100) are essentially the same, while scores that are far from each other (e.g., 20 and 100) are *very* different. This process will be repeated for the groups of sub-criteria under the main criteria. You will have an opportunity to review and go back and change any answers until you feel comfortable with your responses. Weights summing to 100% will be calculated based on these importance scores, without changing the ratios of importance between criteria or sub-criteria.

This process will be repeated for each set of criteria and sub-criteria.

Background on Expert Elicitation

When data is missing or highly uncertain, it is often times necessary to elicit subject matter experts' judgments to augment or complement empirical data or model results. EPA's Expert Elicitation Task Force White Paper (2011) defines expert elicitation as "a systematic process of formalizing and quantifying… …expert judgments about uncertain quantities". In addition, expert elicitation:

- May involve integrating empirical data with scientific judgment, and identifying a range of possible outcomes and likelihoods.
- Includes documentation of underlying thought processes of the experts.
- Is a multi-disciplinary process to inform decision-making by characterizing uncertainty and filling data gaps where traditional scientific research is not feasible or data is unavailable.
- Can be a reliable component of sound science (EPA 2011).

Expert elicitation is widely used by federal agencies, the private sector, academia, and other groups. There is a vast literature on the potential biases of using subjective data and best practices for eliciting reliable judgments (e.g., von Winterfeldt and Edwards1986; Belton and Stewart 2002; Morton et al. 2009; Spetzler and von Holstein 1975).

Appendix A: Exposure Prioritization Decision Model

The intent of the decision model is to evaluate the exposure potential of chemical compounds based on a set of criteria that describe the inherent chemical properties and the use of the compound over its life cycle. Together, these criteria can be used at a screening level to estimate exposure potential. This model does not estimate toxicological parameters, but can be used to complement toxicological studies to characterize overall human health risks.

Following a decision-analytic (specifically multi-criteria decision analysis or "MCDA" approach, the assessment is evaluated by several performance criteria (which are further sub-divided into sub-criteria). For instance, the criteria related to chemical properties include ADME, Bioaccumulation, Physical Hazards, and Persistence. Similarly, use properties are divided into broad life cycle stages, and each stage includes information on quantity produced, potentially sensitive populations, etc. The general architecture of the model is shown in Figure 2 and the full criteria hierarchy can be seen in Figure 3.

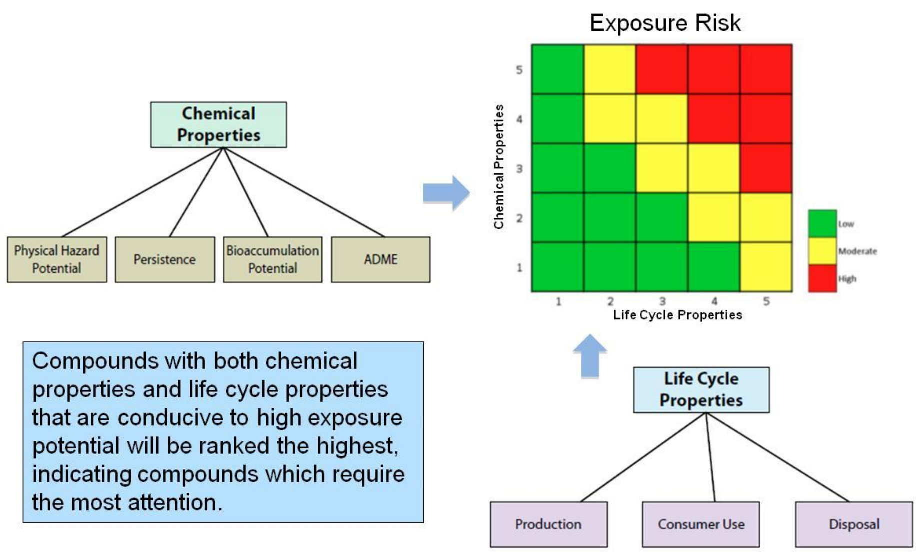

Figure 2 - General Depiction of Decision Model

Each chemical is scored according to their chemical and life cycle properties. Data on chemical properties originate directly from testing, model estimates, or peer-reviewed literature. Life cycle properties would likely originate from the manufacturers and could be provided in standardized surveys. These data are combined following various decision rules to estimate a score for each criterion (Persistence, ADME, etc.). These criteria are then assigned weights by a panel of experts, representing the relative importance of the criteria to overall exposure potential.

Weights and scores are then aggregated to produce a score that can be used to place each compound into a risk category. These categories can be used to inform further, more detailed testing protocols or management strategies.

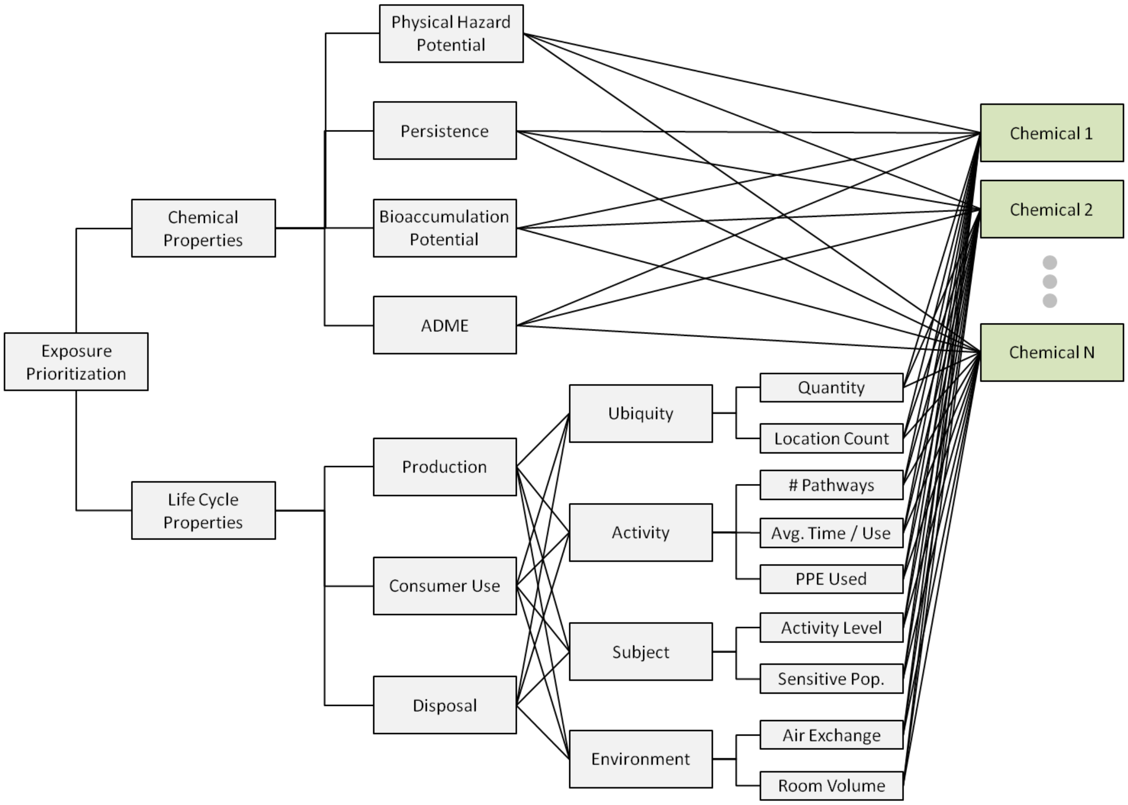

Figure 3 - Full Model Hierarchy

Appendix B: Exposure Challenge Chemicals

Chemical	CAS #	Chemical	CAS #
Formaldehyde	50000	Malathion	121755
DDT	50293	Perchloroethylene	127184
Parathion	56382	1-methoxy-4-(2-propen-1-yl)-benzene	140670
gamma-Hexachlorocyclohexane	58899	decaBDE	1163195
Carbaryl	63252	Trifluralin	1582098
Methoxychlor	72435	PFOS	1763231
Vinyl Chloride	75014	Atrazine	1912249
1,1,2,2-tetrachloroethane	79345	Lead	7439921
Tetrabromobisphenol A	79947	Manganese	7439965
Bisphenol-A	80057	Cadmium	7440439
p-tert-Pentylphenol	80466	Butylhydroxyanisole	8003245
Diethyl phthalate	84662	Perchlorate (Mg salt)	10034818
Di-n-butylphthalate	84742	Tris (l,3-dichloro-2-propyl) phosphate	13674878
1,2,3 Trichlorobenzene	87616	Methyl mercury	22967926
Pentachlorophenol	87865	Phenol, (l,l-dimethylethyl)-4-rnethoxy	25013165
2,4,5-Trichlorophenoxy acetic acid	93765	Nonylphenol	25154523
2,4-D	94757	Hexabromocyclododecane (HBCD)	25637994
Ethylene thiourea	96457	8-2 fluorotelomer acid	27854315
Methylparaben	99763	Aroclor_1260	35065271
Styrene	100425	Aroclor_1254	38380017
n-Hexane	110543	Vinclozolin	50471448
Tris (2-chloroethyl) phosphate	115968	Permethrin	52645531
Aldicarb	116063	Penta BDE	60348609
DEHP, Di(2-ethylhexyl)phthalate	117817	C10-C13 Chloroalkanes	85535848
Hexachlorobenzene	118741	octaBDE	207122165
Ethylparaben	120478		

Appendix C: Multi-Criteria Decision Analysis (MCDA) Frequently Asked Questions

What is Multi-Criteria Decision Analysis?

Multi-Criteria Decision Analysis (MCDA) refers to a group of decision-support methods that impart structure and analysis capabilities to a decision-making process. MCDA methods are particularly well suited for the evaluation and relative prioritization of alternatives based on a multiple criteria that cannot be measured and compared in the same units.

MCDA is a discipline aimed at supporting decision makers faced with making decisions that are characterized by uncertainty and possibly conflicting objectives. MCDA methods allow decision-makers to address their problems by evaluating, rating, and comparing different alternatives, based on multiple criteria, combining both qualitative and quantitative data and information sources. MCDA aims to provide decision-makers with clarity as to the nature of the trade-offs inherent in their decision problems, through an iterative and transparent process. MCDA methods are rooted in risk and decision science, providing a systematic and analytical approach for integrating possibly disparate sources of information, together with an understanding of uncertainty and risk preferences, enabling the coherent evaluation and ranking of project alternatives.

MCDA generally consists of four general steps:

1. Create a hierarchy of objectives and criteria relevant to the decision at hand;
2. Weigh the relative importance of each objective and criterion;
3. Score how well each alternative performs on each criterion;
4. Combine scores across criteria to produce an aggregate score for each decision alternative.

What is the general background of MCDA and how has it been historically applied?

Scientists have historically used the MCDA process on a broad range of interdisciplinary issues, from infrastructure projects and economics to policy-making and environmental science. MCDA is most widely utilized in economics, social science, and environmental studies. Researchers with the US Army Corps of Engineers (USACE) are internationally recognized for their contributions to MCDA theory and practice. USACE staff has applied MCDA methods to the evaluation and prioritization processes of many U.S. government agencies, including DOD, DOS, DHS, HHS, EPA, and USAID. Their experience working with multiple U.S. Government agencies, combined with their prominence in the field of risk and decision science, supports their role in the ExpoCast process.

How does the MCDA process apply to the Exposure-Based Prioritization effort? How do the elicitation surveys feed into this methodology?

In decision analysis, expert elicitation is often used as a means by which to obtain the opinions of experts on values and/or uncertainties relevant to the decision problem being considered. Typically, these elicitation exercises focus subjects for which there is significant uncertainty, complexity, and/or insufficient or limited data. For the exposure-based prioritization decision problem, much of the knowledge concerning the relative importance of exposure-based criteria – a crucial piece of information given the relatively date-poor decision-making environment – rests in the minds of stakeholders. The elicitation surveys are intended to translate experts' judgments into quantitative inputs for the decision model.

What are some examples of projects where MCDA methods have been applied?

USACE ERDC personnel have considerable experience in assisting partner government agencies and departments with MCDA processes. USACE and ERDC routinely deal with situations such as this. Past projects conducted by the USACE Team include the following U.S. interagency projects:

USAID/BTA: Sustainable Infrastructure Development in Afghanistan
DHHS: Chemical Risk Communication Portal
FDA: Supply Chain Management for Imported Drugs
DHS: Chem/Bio Countermeasures Prioritization
DOD: Capability Gaps Prioritization in Small Arms Program
EPA/DOD: Remediation of Contaminated Sites
DOD: Environmental Management at Military Installations Affected by Climate Change
USACE Districts: Restoration Planning for Coastal Louisiana and Mississippi
DOD: Portfolio Approaches for Dams Prioritization

Why is this process unique and what is the advantage over other decision-making processes?

In general, ad-hoc, qualitative or quantitative (e.g., MCDA) methods have been used to support decisions in similar previous situations. Ad-hoc and qualitative decision-making does not have rigor and transparency necessary to address the stated needs of the EPA. Decision-analytic methods including portfolio decision analysis, risk management and other tools from risk analysis, utility theory, and modern economic theory can help to address complexities of the project challenges. MCDA is a reasonable compromise tool that allows integration of technical and historical data with expert value judgments. MCDA allows us to understand overall stakeholder view points and identify areas of potential compromise.

How do you synthesize and qualify the potential diverse opinions that will be presented by multiple experts representing different disciplines?

In many applications of decision analysis, the decision analyst will seek the opinions of several experts, rather than relying solely on the judgment(s) of a single expert (or on the analyst's own expertise). This raises the question of how to combine or meaningfully aggregate these expert opinions to form a consensus value to be used in the decision model. Several approaches, including weighted averages and Bayesian analysis, have been utilized to arrive at combined values for the group. The complexity of the aggregation approach employed depends on the nature and quality of information collected during the elicitation sessions.

How do you account for over-confidence and expert biases towards the criteria most relevant to their home agency or area of interest?

Part of the responsibility of the decision analyst is to understand how obtaining information from experts might be challenging due to: (1) the information may be sensitive; (2) the natural procedure for processing information in one's mind often results in (unintentionally) biased judgments; and (3) the expert may have a vested interest in misrepresenting information. The deleterious influence that such factors have on the relevance and credibility of the overall analysis are reduced by using four devices: (1) iteration with consistency checks; (2) assessments with different individuals; (3) decomposition; and (4) sensitivity analysis. Iteration with consistency checks suggests that information is gathered using redundant lines of questioning; resulting inconsistencies are investigated until consistency is achieved. Use of judgments about the same factor obtained from different qualified stakeholders also has additional virtue; in many problem domains, it is often the case that "many heads are better than one". Decomposition involves dividing the factor being assessed into component parts and obtaining judgments on the individual components. Different individuals should provide the component inputs, which are then aggregated to provide estimates of the original factor. Lastly, sensitivity analysis can identify decision problem elements that are crucial for the evaluation of the model's outputs, which in this case is the ranking of exposure potential.

Where does the scientific reliability of this method come from? How are the results from this process verified?

The purpose of decision analysis is to help decision-makers structure and evaluate complex decision problems under uncertainty. In using these tools, the goal is to provide decision-maker with insights that allow them to make sound decisions with clarity and deliberation. In the first instance, the strength (or "scientific reliability") of decision analysis stems from its solid (mathematical) grounding in the foundations of modern economic theory. Secondly, decision analysis provides a number of analytic tools that allow decision-makers to structure complex decision problems where risk and uncertainty are pervasive concerns. Finally, these methodological tools provide decision-makers with rational and coherent means by which to formally evaluate and compare competing policy alternatives or options. In multi-stakeholder and/or multi-expert settings such as the one we are confronting here, there are benefits to using decision analysis in ways that help foster shared vision and understanding of common goals and objectives, as well as the endogenous and exogenous factors that are likely to be most relevant to the decision-making process. Used properly, decision analysis can be used as a vehicle for understanding both the causes and consequences of possible disagreements between experts, and identifying strategies (e.g., additional information gathering, etc.). As with any modeling effort, the analysis is only as credible as the values that enter into the decision models that are used to inform the decision-making process. Our goal here is develop a decision-analytic framework that is requisite to the task at hand; by this we mean that the model captures all of the key values and parameters that are deemed most relevant to the decision-making process by all stakeholders.

Appendix D: Contact Information

Points of Contact:

EPA	USACE
Daniel Vallero National Exposure Research Laboratory U.S. Environmental Protection Agency Vallero.Daniel@epa.gov 919-541-3306	Zachary Collier USACE Engineer Research and Development Center Zachary.A.Collier@usace.army.mil 601-634-7570
Peter Egeghy National Exposure Research Laboratory U.S. Environmental Protection Agency Egeghy.Peter@epa.gov (919) 541-4103	Matt Wood USACE Engineer Research and Development Center Matthew.D.Wood@usace.army.mil 978-318-8793

III. References:

Mitchell J, Pabon N, Collier ZA, Egeghy PP, Cohen-Hubal E, et al. (2013) A Decision Analytic Approach to Exposure-Based Chemical Prioritization. PLoS ONE 8(8): e70911. doi:10.1371/journal.pone.0070911

Environmental Protection Agency (2011) Expert Elicitation Task Force White Paper