Socioeconomic Valuation of Hazardous Chemicals Control: State of the Art and Future Prospects

Workshop Summary

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Socioeconomic Valuation of Hazardous Chemicals Control: State of the Art and Future Prospects

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Author(s)	Meg Postle Marco Camboni
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Table of contents

1 Overview

1.1 Background to the Workshop

The valuation of the environmental benefits of hazardous chemicals control is required under the REACH Regulation and the Water Framework Directive (WFD). An important sub-group of hazardous chemicals that may require risk management under REACH are known as 'Substances of Very High Concern' (SVHCs). In the context of the environment, SVHCs include Persistent, Bioaccumulative and Toxic (PBT) or very Persistent and very Bioaccumulative (vPvB) substances, or those giving rise to an "equivalent level of concern", such as endocrine disrupters (and it is likely that SVHCs will also be considered for prioritisation under the WFD in future). For such substances, it is recognised that accumulation in the environment and food webs is highly likely, but unpredictable levels (and effects) could occur in people or (especially) the environment over long time periods. Experience has shown for example that they can accumulate in parts of the environment remote from their source and that such accumulation is practically difficult to reverse.

The assessment of environmental risks and appropriate policy action associated with such substances is confounded by uncertainty, due to the complexity of environmental and human systems and their interactions. Standard approaches to risk management have been problematic, often being slow to diagnose them, tolerating too much dispute about harm and cause before taking action, and only acting once the problem is obvious and/or costly and difficult to remedy. As such there is widespread policy support for action, often on precautionary grounds, to avoid such uncertain, but potentially damaging, environmental risks. Nevertheless, there remains a large evidential challenge in making a socioeconomic case for reducing the emissions of such substances since the costs of control measures are often clear to see, whereas the economic value of benefits associated with such control is difficult to evaluate, particularly where the scientific judgments involve precautionary control.

On the 6th of September the Royal Society of Chemistry, UK Chemical Stakeholder Forum and the Environment Agency for England hosted a Workshop in London, the aim of which was:

> "to identify and assess current state of the art and future prospects for valuing the benefits of precautionary control of hazardous chemicals for which environmental impacts are uncertain."

The Workshop was attended by 30 people coming from regulatory, academic and consultancy backgrounds. Attendance was by invitation only, with the mix of invitees chosen with the aim of generating discussion between the scientific and economics communities. The majority of attendees were from the UK, as well as from Finland (representing the European Chemicals Agency), the Netherlands (academics) and Germany (Umweltbundesamt). It also included individuals who sit on the European Chemical Agency's Risk Assessment and Socio Economic Analysis Committees. A full list of participants and their affiliations is available in Annex 1 to this report.

The workshop programme took as its starting point the following themes:

- the policy context (for REACH and WFD art 16) for which assessment of the costs and benefits of precautionary control of chemicals is required;
- the nature of the environmental threat for which the valuation of the benefits of precautionary control of hazardous chemicals is required;

- the extent to which control of hazardous chemicals on precautionary grounds is compatible with/can be placed within the utilitarian framework of Cost-Benefit Analysis;
- valuation case studies that seek to evaluate the benefits of control of hazardous substances motivated by precautionary action towards environmental risks; and
- the need for greater dialogue between economists and scientists to engage on further interdisciplinary understanding of the nature of the environmental problem and to make it more tractable in terms of their respective methodologies, scientific underpinnings and language.

1.2 The Workshop Agenda

The Workshop comprised a number of presentations to both set the scene and present the results of recent research, followed by a plenary discussion organised around a number of key questions arising from or linked to the presentations.

The titles of the seven main presentations given in the first half of the Workshop, together with the names of the presenters, are:

- Introduction: Socioeconomic Valuation of Hazardous Chemicals Control – State of the Art and Future Prospects (Bill Watts);
- The nature of the environmental threat from PBTs: the science perspective (Gera Troisi/Mark Scrimshaw);
- Guiding decision making on the authorisation of PBT and vPvB chemicals under REACH: A stock pollution approach (Silke Gabbert);
- Economic valuation of environmental impacts in socioeconomic analysis under REACH: Possibilities and limitations (Sarah Bogaert);
- Willingness to pay for the combined effect of uncertain environmental and human health risks: the case of micropollutants in Switzerland (Roy Brouwer);
- Economic benefits of controlling PBT/vPvB substances: Two case studies (Susana Mourato/Stavros Georgiou);
- Socioeconomic Valuation of Hazardous Chemicals Control: Issues, Challenges and questions for Discussion (Meg Postle).

A brief summary of each of the presentations is given in Section 2 below, with the presentations then attached in Annex 2 to this report.

The questions discussed during the plenary were developed prior to the Workshop by the Rapporteur, drawing on ideas from the Workshop organisers. These questions are presented in Section 3 below, together with a summary of the main conclusions from the discussions held in relation to each.

2 The Workshop Presentations

2.1 Introduction: Socioeconomic Valuation of Hazardous Chemicals Control – State of the Art and Future Prospects (Bill Watts, Environment Agency)

Mr Bill Watts gave the first presentation of the Workshop and set out the expectations for the day. In his presentation he stressed that the Workshop was about valuing the benefits of hazardous chemicals management and not about reform of any existing policies or challenging the validity (or not) of the precautionary principle as the basis for regulating hazardous chemicals. Furthermore, the aim was to consider the needs of regulators in relation to the range of policy domains covering hazardous chemicals – REACH, the Water Framework Directive (WFD), the Industrial Emissions Directive (IED) and others.

In this respect, the presentation stressed the importance of recognising that the adoption of a precautionary approach to regulation affects both companies and wider society; these include costs stemming from:

- Loss of market, consequent changes to production processes and the costs of abatement technologies;
- Passed-on costs, loss of useful substances and substitution by substances which may be equally harmful.

At present though, there are difficulties in providing quantified estimates of the benefits of taking action to set against such costs; and this is particularly true in the case of vPvB substances, due to the lack of a known toxicity mechanism. Furthermore, as these substances accumulate in the environment, the potential to reach a tipping point in terms of the level of future damages increases. The potential for adverse interactions between chemicals may also increase and to the extent that they act additively one with another, then a given threshold (if one exists) may be exceeded collectively, though not exceeded at the level of the individual chemical.

The problem for regulators is then one of uncertainty as to the benefits of adopting precautionary controls on the use of PBT and vPvB substances. In the face of this uncertainty, there are the risks of unnecessary bans or the failure to ban substances which result in significant future damages to the environment or health. Moreover, given the overlapping nature of the regulatory mechanisms in place, there are questions over the best point of intervention. Given the potential for mixture effects, we may also wish to appraise and regulate PBTs as a group rather than on a substance by substance basis.

Within the context of this Workshop, this raises the following issues / questions:

- Valuing hazardous chemicals' effects requires an understanding of their impact on the welfare of the community. (Interpreting scientific data on effect in a way that people understand and value is essential.)
- Valuation data should be used across all regulatory regimes, REACH, WFD or Industrial Emissions Directive. The science relates to the chemical, not the regulatory process.

- Valuation of effect, chemical by chemical may neither yield usable results nor be meaningful. Does this mean grouping of chemicals may be needed to value effect? If so, how should they be grouped, by welfare end point?
- People value the avoidance of the risk. There is likely to be an insurance premium which the public would be willing to pay to mitigate the "risk".
- We may need to re-assess the use of incomplete scientific data to inform the public's assessment of potential risks from hazardous chemicals. We need to be systematic in describing effects and use value transfer where we can, but not be shy of new primary valuation.
- Finally, there is the issue of which is the most appropriate measure of benefit: Willingness to Pay (WTP) or Willingness to Accept, or something else?

2.2 The nature of the environmental threat from PBTs: the science perspective (Gera Troisi/Mark Scrimshaw, School of Engineering and Design, Brunel University)

Dr Gera Troisi's presentation provided a scientific context to the Workshop. It started with a review of the properties of PBTs and the types of impacts that they may give rise to in the environment as a result of both their persistence and their bioaccumulative nature. The focus was on organohalogens, as their effects are well-characterised in wild mammals (used as sentinel species for effects on humans) and give rise to endocrine disruptive properties with similarities to emerging PBTs. Dr Troisi presented data on human exposure (and more specifically on dietary exposures of Artic communities) showing how Tolerable Daily Intakes of chemicals already controlled for decades are exceeded due to the high consumption of fish and marine mammals. Moreover, there is a potential for transgenerational peri-natal exposure, since some of these chemicals can pass the placental barrier and indeed have been observed in breast milk and cord blood in significant concentrations. She noted that exposure during the critical periods of cell differentiation and organogenesis results in reprotoxic effects, endocrine disruptive toxic mechanisms on wild mammals and, ultimately, effects on humans. Adverse effects on humans include:

- Neurological effects;
- Thyroid dysfunction;
- Reproductive & developmental effects;
- Thyroid dysfunction and thyroid cancer;
- Infertility;
- Congenital (e.g. chryptochordism) and pathological deformities of reproductive tract, including cancers.

Evidence has been collected through *in vitro*, *in vivo* and epidemiological studies. However, quantity and quality of data are variable and validated testing methods are still lacking for a range of health endpoints. It was stressed that regulatory triggers are mostly set for individual chemicals, while environmental exposures occur to a set of toxic chemicals.

Dr Troisi then presented some of the findings of the studies related to exposure to flame retardants (PBDEs, HBCDD), organohalogens (DDT, PCB, alachlor), fluorosurfactants (PFOS) and cyclic methyl siloxanes. She concluded her presentation by highlighting issues around the paucity of data and scientific uncertainties and how these may impact upon risk perception and risk communication.

2.3 Guiding decision making on the authorisation of PBT and vPvB chemicals under REACH: A stock pollution approach (Silke Gabbert, Environmental Economics and Natural Resources Group, Wageningen University)

Dr Silke Gabbert started her presentation with an introduction to Authorisation under REACH, and the need for applicants to demonstrate that socio-economic benefits of the continued use of a substance outweigh the risks to human health or the environment for an Authorisation to be granted.

She then set out an analytical modelling approach designed to capture the costs and benefits of both an "applied for use" and the "non-use" scenarios that need to be analysed as part of a SEA submitted to support Authorisation of a non-threshold substance (such as a PBT or vPvB). The framework adopts a stock pollution approach which takes into account the accumulation of the pollution stock over time and rate at which emissions to the environment degrade or decay (i.e. the half-life of a PBT or vPvB in the environment). Within this model, the change in stock over time will depend on the level of emissions in different periods and the degradation rate, with the stock converging to a steady state at some time period in the future.

The implication is that Authorisation decisions for PBTs are essentially an optimal timing problem, with the optimal time for removing a PBT from use depending on whether the relationship between emissions and damage costs is linear or non-linear:

- Where the relationship is linear (constant marginal damage costs over time), then the decision becomes one of removing the substance now or never.
- Where the damage function is non-linear, then the timing of control depends on the initial stock and the level of persistence of the substance. The higher the initial stock and the greater the persistence, the earlier in time that the substance should be removed from the environment. In this case, the decision depends on whether or not granting of an Authorisation is reversible.

A research agenda was then set out, aimed at providing a better understanding of the implications of different variables within the above model, including different emission pathways, different shaped damage and benefit functions, different decay functions, variations in the discount rate, etc.

2.4 Economic valuation of environmental impacts in socio-economic analysis under REACH: Possibilities and limitations (Sarah Bogaert, Arcadis, Belgium)

Ms Sarah Bogaert reported on the results of a study commissioned by the Dutch National Institute for Public Health and the Environment (RIVM) with the objective of investigating the availability and applicability of economic valuation methods for assessing environmental impacts in the framework of socioeconomic analysis in a REACH context and to identify areas in need of future research. The starting point of the analysis consisted of previous recent studies conducted by RIVM, RPA, ECETOC and WCA, comparing the outcomes of the risk assessment and impact assessment studies and identifying areas characterised by high uncertainty and lack of knowledge (for example, impacts on ecosystem functionality). ARCADIS took this a step further and investigated the suitability of the various economic methods in valuing environmental impacts comparing the outcomes of

Environmental Impact Assessment with the input data needed for monetary valuation; this helped develop a decision tree to guide the optimal choice of a valuation method.

Four illustrative cases explored further the methodologies with potential:

- Avoidance cost method to test whether the implementation cost of environmental reduction measures can be used as a proxy for the economic value of environmental impacts (using cost-effectiveness analysis);
- Combining Stated Preferences methods with the Potentially Affected/Disappeared Fraction of Species (specific focus on potential of water quality ladders);
- Scaling of reference valuation cases for groups of similar PBT substances and for groups of substances with similar hazards; and
- Potential of Ecosystem services approach for economic value transfer.

Within each case, the difficulties in using the EIA outputs were spelt out leading to recommendations for further research. It was concluded that the combination of the use of the Stated Preference Method with information on the Potentially Affected Fraction that can be derived from use of Species Sensitivity Distributions and a probability density function for environmental concentrations had potential and should be an area for further research; similarly, the further development of an Ecosystem Services approach and the rescaling of reference values are also considered to be promising methods. Further information can be found in the ARCADIS report.

2.5 Willingness to pay for the combined effect of uncertain environmental and human health risks: the case of micropollutants in Switzerland (Roy Brouwer, IVM, VU University Amsterdam)

Professor Roy Brouwer of IVM reported on the results of a willingness to pay (WTP) study carried out with the aim of deriving estimates of the value of reducing the discharge of micropollutants (15 chemical compounds from pharmaceutical, personal care products, pesticides and industrial uses which are present in very low concentrations µg/l or ng/l in the aquatic environment) into water bodies in Switzerland through the upgrading of waste water treatment plants. The policy context is one of uncertainty; although the micropollutants may potentially have endocrine disrupting effects on aquatic ecosystems, harmful effects on human health are largely unknown and not yet proven.

The research had to address the question of how to represent these uncertain effects to validly and reliably gauge the public sense of urgency and which is the best form of risk communication. Although there are many stated preference studies that value small changes in risk, few examine the question of how the approach to risk communication may affect welfare estimates. No prior studies were identified that examined the effects of risk communication tools – such as a risk ladder – within a repeated choice experiment. A key hypothesis tested in this study was that the nature of a repeated choice experiment would decrease any possible procedural variances in WTP valuations that would be introduced through the use of a risk ladder.

The research found that most people had some familiarity with the information provided on the potential effects of the micropollutants of concern, with most also perceiving them as either risky or somewhat risky (and the proportions falling into these two categories varying across the sub-samples with and without risk ladder). The study found furthermore that WTP estimates did vary across the with and without risk ladder sub-samples, with the valuations derived using the risk ladder being more than 30% lower than those expressed in response to the survey without the risk ladder. This is exactly the opposite result of what has been found in the contingent valuation literature, where the risk ladder inflates WTP. The results of the study show that the use of risk ladders may help to improve risk communication, but are unable to confirm the hypothesis that the use of a risk ladder helps to significantly reduce preference and choice uncertainty surrounding the resulting WTP estimates. As a result, further research is suggested with regard to survey design, whether variations in the level of absolute and relative risk would generate different results, ie how the position of a given risk in the risk ladder matters.

2.6 Economic benefits of controlling PBT/vPvB substances: Two case studies (Susana Mourato, London School of Economics and Stavros Georgiou, Health and Safety Executive)

Professor Mourato and Dr Georgiou reported on two Master's theses presenting case study (siloxanes D4 and D5 / deca-BDE) research aimed at monetising the economic "option" value of controlling PBTs. The research was carried out using willingness to pay (WTP) methods in the presence of poorly understood effects and risks, incomplete information on the damage function chain and concerns over scope insensitivity. The two studies were also designed to serve as pilots to test the ability of deriving estimates of public WTP for reducing the environmental accumulation of these substances, as well as the benefits they impart.

The questionnaires for both the cases studies followed the same outline:

- Firstly, there was a demographics characterisation of the population sample;
- Secondly, information was provided on the uses and particular benefits delivered by the chemicals (personal care products for D4/D5 and flame retardants in textiles for deca-BDE);
- Thirdly, the questionnaire investigated the behaviour and attitudes of the respondents toward the environment;
- Fourthly, different policy scenarios were proposed (BAU: high accumulation of substances in the environment; substitution with chemicals with less desirable properties or more expensive alternatives, leading to no longer releases of the substances in the environment but with persistent current levels); and
- Finally, respondents were invited to choose between different bundles of attributes.

The case study on siloxanes was a split sample involving two surveys, one for each of the chemicals. Approximately 414 respondents completed each split sample drawn from the UK population (with a large number of respondents excluded due to the speed at which they completed the on-line questionnaire). Respondents were shown detailed descriptions of the product benefits and costs and made aware of the potential loss of quality if the chemicals would be substituted, of the nature of PBTs and vPvBs and of the costs to reduce their presence on the water bodies, resulting in an increase in their annual household bills;. They were then given detailed descriptions of the product quality and levels of environmental accumulation from which they could choose, and asked to make choices on each card. Each choice card had three options with three attributes (environmental accumulation, personal care product quality and annual household bills increase) with a randomly generated level. Each respondent was shown six choice sets, randomly assigned from twenty choice cards. The only difference between the two surveys was that for D4 information on its toxic properties was given while D5 was described as non-toxic, based on current information. The key finding is that respondents expressed a willingness to pay for the reduction of those substances for which the effects are unclear. The comparison between the two samples also showed that there was an additional WTP to decrease accumulation of the toxic substance of £5 per annum.

The most important limit to this study was its online nature, as this prevented a follow-up on the responses to the survey. There may also be issues as to the time in which the surveys were completed with one third of the responses considered valid having been completed in less than 10 minutes (although responses provided in less than 6 minutes were excluded). There are also questions about the survey design and whether the choice of attribute levels impacted on the WTP results.

The second case study was also a web-based choice experiment with three survey split samples:

A. The first survey valuing the environmental risks from deca-BDE;
B. The second survey valuing the environmental and human health risks from deca-BDE;
C. The third survey valuing the environmental and human health risks from all PBTs.

A risk ladder was used to provide a visual aid to compare the risk of death due to a household fire and other death risks and information on the alternatives to deca-BDE being more expensive and potentially not as effective in preventing fires provided. As for the first case study, different levels for four different attributes were defined and respondents were invited to choose between different choice cards. As for the first case study, this survey found a positive WTP for a decrease in the relative level of risks to wildlife, with WTP rising for those who indicated a high concern for wildlife populations. The inclusion of questions concerning human health risks decreased WTP for wildlife risks. Across all surveys, the total WTP values ranged from £129 to £145, even though in Survey B and C the attribute for human health risks dominates that of wildlife risks compared to Survey A, and that Survey C values all PBT compared to just deca-BDE. This suggests that WTP for precaution may be “fixed” despite the changes in scope between surveys. Moreover, valuing all PBTs does not increase the WTP for both reduced human health and wildlife risks.

2.7 Socioeconomic Valuation of Hazardous Chemicals Control: Issues, Challenges and questions for Discussion (Meg Postle, Risk & Policy Analysts)

Ms Meg Postle, also acting as rapporteur of the workshop, reported on the current issues and challenges facing economists from a practitioner’s perspective and presented the questions for the plenary discussion. She stressed the need to balance the uncertain benefits from taking a precautionary approach to the regulation of PBTs and vPvBs against the economic costs to society from the loss of a chemical; this balancing requires an understanding of the environmental hazards posed by PBTs, of the associated risks and, ideally, how these translate to effects. Moreover, it may also require consideration of synergistic and mixture effects. For decision making purposes, it may also require scientific data to then undergo some form of valuation or translation to a human welfare perspective.

In this respect, the starting point has to be the consideration of the outputs of the risk assessment, where these may include:

- Toxicity effects in different environments (media): aquatic, terrestrial, higher predators, etc.
- Toxicity in different types of organisms: microbial, invertebrates, vertebrates, etc.
- Toxicity for different endpoints: survival, growth, reproduction, abnormalities, etc.
- Other effects: persistence, bioaccumulation, endocrine disruption.

The output of RA will be a Risk Characterisation Ratio for the most sensitive species, which is just a ratio indicating whether or not a risk is considered “acceptable”. SEA however needs the data underlying these and should also consider effects on other species and/or ecosystems. Another key issue is the uncertainty surrounding the use of PNECs, as they vary in terms of the endpoint assumed, there may be varying sensitivities for different species, they may reflect acute or chronic effects, will include assessment factors, etc. Moreover, it is very difficult to account for the long-term and on-going nature of effects associated with PBT and vPvB properties, especially in the absence of monitoring data on environmental concentrations and our current lack of knowledge about the complex interactions between multiple species.

Ms Postle then provided a summary of some of the challenges implicit within the preceding presentations, together with those she has identified from her experience in trying to apply SEA methods for both public authorities and industry. In particular, she noted the need to consider a combination of SEA methods in order to overcome the lack of data and the high level of uncertainty.

The questions proposed by Ms Postle are presented in Section 3 along with the discussion during the plenary final session of the conference.

3 The Plenary: Key Questions and Main Conclusions

3.1 Question 1: Do People value precaution? And if so, how can we best reflect or capture this value?

Although this was the first question put to the plenary, there were no discussions specific to this question. Instead, this question is best answered by drawing on the overall discussions held during the Workshop.

People appear to value precautionary action against hazardous chemicals for which environmental and human health impacts are uncertain. Moreover, first results indicate that they may be able to express this value in terms of preference-based economic values. This stems from the results found in the stated preferences surveys presented by Professor Roy Brouwer and Professor Susana Mourato. However, from these first surveys, it is not clear what component of economic value this relates to (use, option, bequest, altruism), what the drivers underlying the valuation are (i.e. in terms of risk perceptions, understanding of the scientific issues, uncertainty, etc.), and whether a valuation relates to the group of similar substances or can be derived at the individual substance level in the context of PBTs and vPvBs. As a result, more research is needed before it is clear whether or not we can reliably report the value of people's preferences towards the risks and uncertainty presented by PBTs and vPvBs using stated preferences methods. Such research needs to explore what underlies people's perceptions of the risks posed by such chemicals, whether and how their attitudes and preferences towards these risks vary depending on the different properties or characteristics of the substances and their use, how best to communicate such risks, and thus what approaches are the most appropriate for eliciting relevant valuations.

It was also stressed that we should not focus only on the use of survey methods. Revealed preferences methods may also provide an important set of tools for valuing the avoidance of certain types of risk. For example, it is important that the more tangible effects of hazardous substances in terms of their impacts on health care costs and yields from environment-dependent production activities are not ignored in SEAs, as they may translate to significant economic impacts. It is also clear though, that such methods are not applicable to vPvB substances and may have only a limited role in relation to the uncertain environmental and human health threats posed by PBT substances.

3.2 Question 2: What is the real data gap between what risk assessors can provide and what economists need?

A key issue raised by the presentations is whether there really is a significant gap between what risk assessors produce and the information that economists need in order to infer the value of the benefits of reducing hazardous substances from a welfare economics perspective. If the answer to this question is yes, then there are linked questions as to whether the gap relates to information on 'stocks' and exposure, cause and effect, or fate and transfer mechanisms? In addition, if these gaps will always be there, then what are their implications for the assessment of costs and benefits in socio-economic analyses (SEA)?

There was a general agreement that the current EU risk assessment (RA) process provides information in absolute terms, i.e. whether there is an "unacceptable risk" or not. However, it must be recognised that, for example under REACH, this assessment may be based on a relatively small data set, which may actually be based on an extensive amount of read-across from other substances, and which will incorporate assessment factors. Information on both the extent and quality of the underlying data and the uncertainties surrounding it could be communicated better, and this is an area that should be addressed. Furthermore, there are data that are not necessarily reported in a RA, but which underlie its conclusions, that could be reported and which may be of value; a clear example of this is the type of ecotoxicological data needed to generate Species Sensitivity Distributions (SSDs). In addition, there is a need for the science to better communicate information on pathways and mechanisms. It should also be remembered that to date we have been regulating relatively data rich substances; in the future, one can expect there to be even less information on hazard properties and exposures.

The focus in communicating RA data should be on identifying what information decision makers and the public need to make a considered judgment on the risks that confront society. Decision makers in particular want both the output of a cost-benefit analysis (CBA), and a good understanding of the underlying science, where this includes data on the scale and timing of exposures and hence the potential magnitude of impacts; without this underlying data they may lack a proper context for the results of any CBA and hence for decision making. In providing this information consideration also has to be given to the requirements of the different regulatory processes, and whether these are essentially the same. The data needed by decision makers in relation to REACH is different in some respects from that needed under the WFD, as the nature of the decisions made under Authorisation and Restrictions are different.

However, the European Commission[1] has now recognised the need to assess the extent of and reinforce the synergies between the key legislative acts, namely, the WFD, the REACH Regulation, the Plant Protection Products Directive, the Biocidal Products Directive and the Industrial Emission Directive. This indicates that the same data and analyses may be relevant to all regulatory regimes. It also suggests that there may be new challenges in how to use those data and on how to present analysis results: for example, how should one apportion the costs and benefits of action across different regulatory interventions and across different PBT substances, where more than one may be linked to a particular type of effect? For REACH Authorisation purposes, information is needed on impacts in order to make decisions on the residual risks associated with the continued use of SVHCs; however, it may be impossible to apportion certain types of environmental effects (and impacts on 'man via the environment') to a single SVHC.

Even though we are unlikely to ever be able to fill all the scientific data gaps, decision makers still have to take decisions, thus we need to adapt to the current decision-making context. One way of doing this would be to convey better what we don't know, e.g. by adopting a more probabilistic framework. Another would be to identify what level of information is sufficient to take a decision. For example, do we need to provide information simply on effects along the entire damage-function chain and or is it possible and sufficient to value only effects in particular links, for example, those upstream of the last link in the chain?

Answering questions such as these and determining what is likely to be "adequate" requires a better understanding of the sensitivity of decisions to the nature of the potential impacts, their potential magnitude and their irreversibility (i.e. the scope of the uncertain risks to be addressed). For example, if one can only ever derive a total willingness to pay "budget" (i.e. a maximum amount that individuals' are willing to pay across all SVHC given their own budget constraints) for reducing the presence of PBTs in the environment, then a clear understanding is required as to how this budget

[1] As for example in Art 7a of Directive 2013/39/EU amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy.

may be used in decision making as part of the REACH Authorisation process; and, what rules should apply when using this budget across other regulatory areas, e.g. under the WFD? One possible approach is to weight different types of PBTs by their importance, depending on characteristics of the environmental/human health threat e.g., the scale of the potential risk, temporal change aspects, exposures, etc. Though of course, weighting individual chemicals within a basket requires scientific data, which is often unavailable. It should also be borne in mind that this type of approach is not envisaged in the legislation and, of course, is not readily applied to vPvBs where the lack of significant toxicity does not matter (at least within the context of REACH).

3.3 Question 3: The presentation on stock pollution approach suggests that the scientific case for control on precautionary grounds may vary across different types of SVHCs. Should such an approach be promoted and what are the implications for the management of vPvBs?

It was agreed that the issue of "pollutant stocks" is important to understanding the stream of costs and benefits of taking action and hence the optimal timing of controls: it provides information on tipping points which could be used to inform the prioritisation of chemicals for control. It also helps make explicit the parameters underlying the desire for precautionary action (time, irreversibility, etc.). In this respect, it may aid transparency within the decision making process.

An issue for the WFD process is whether and where source reduction measures should be used, and whether control is taken at the national level or at the EU level. In other words, should the UK install additional sewage treatment plant (STP) in order to achieve Environmental Quality Standards as soon as possible despite the high costs involved, or should the UK let REACH deal with the issue at the EU level? This is a question of timing in terms of REACH Decisions for WFD controls and investment in STP; there are also associated issues of the co-removal of chemicals with different types of treatment and hence how to deal with the staging of controls.

There is a question though as to whether this type of model could be adequately populated, given that it assumes an ability to quantify both costs and benefits. This raised suggestions that it might be possible to establish some general rules based on expert judgement. For example, the model highlights the importance of time, and the results are likely to be highly sensitive to half-lives as there is significant variance across substances with respect to their half-lives. Furthermore, although there is increasing evidence on the persistence of substances, there is very little data on half-lives and no regulatory requirements for its generation.

3.4 Question 4: Methodological frameworks such as that proposed by RIVM promote a tiered approach, using different techniques for quantifying effects. Is further work required on the development of such techniques? If so, which ones should act as the focus of such research?

The key conclusion from the discussion on this set of questions was that we need a suite of tools, as each chemical risk management case is different and may require a different approach towards assessing benefits. A note of caution is also needed though, as it is unlikely that we will ever be able to fully quantify and value the full range of benefits associated with the control of SVHCs, particularly where there is considerable uncertainty over their potential impacts on the environment (and man via the environment).

In terms of the types of tools that may be important, these clearly include both revealed and stated preferences methods:

- Revealed preferences have a strong role to play in complementing stated preference methods, as people buy insurance, use environmentally friendly products, etc. For example, revealed preferences may be used to establish scenarios for use in stated preferences surveys. A key concern with the use of such methods is that that people may not know or understand the link is between what they are buying and environmental impacts. This issue may be more pronounced in the case of PBTs and vPvBs given the uncertainty surrounding future effects.

- Stated preferences provides a means of trying to capture the extent to which people value a reduction in uncertain future risks, although as discussed above there are also questions over what is being captured in such surveys. A series of questions were raised though with the use of these methods. This included questions over:

    - Whether we need to understand better risk perceptions in relation to these types of chemicals before undertaking more surveys?
    - How much information should be given to respondents, in order to properly contextualise the problem? What can be learned from the risk perception literature?
    - How important is it to provide additional information with regard to the impacts of moving to alternatives (e.g. a worker health trade-off)? Should this be taken into account in the survey or should this be addressed separately?
    - Whether the types of relative risk approaches used in the surveys presented in the first half of the workshop are appropriate? Do they need to be refined?
    - How can respondents' answers be verified? What type of qualitative testing is needed?

With regard to some of the other tools identified in the morning presentations, the use of Species Sensitivity Distributions was discussed briefly as being of potential value as an input to both revealed preferences and stated preferences valuation work. The potential use of an ecosystems services framework was discussed in more detail under Question 5 below.

More generally, in order to understand the role that the various methods could play, it was suggested that a series of case studies should be developed. These case studies should be realistic so that it is possible to see what might work and what might not work in practice. Comparisons of the resulting estimates of benefits could also be important to testing for convergence and the existence of anomalous results. The case studies would clarify the need and/or value of using a combination of tools, in terms of the impacts covered and the value of the resulting information to the public and decision makers.

The idea of creating an overall WTP budget for reducing the risks posed by PBTs and vPvBs was again raised. The focus at this point in the discussions was the need for a framework for relating such a budget to the outputs of risk assessments and to the differences between chemicals (in their properties, use and exposure characteristics). The aim of this framework would be to develop a system for allocating the overall budget across substances via some form of risk/benefit apportionment.

It was highlighted that a total budget based approach was adopted as part of the use of the results of a stated preferences study carried out for the WFD. An overall budget was derived through a

WTP survey for improvements in water body status at a regional level and this budget was then allocated across river basins. It was agreed though that, in the case of SVHCs, adopting a similar approach would require the creation of a robust mechanism for allocating the WTP budget - one which would need to take into account the level of uncertainty that may exist around toxicity, the lack of toxicological data for vPvBs as compared to PBTs, and the degree to which persistence should be the driver rather than toxicity. Once developed, this type of framework could be of value across the different regulatory frameworks.

Difficulties in making such an apportionment given the current levels of scientific uncertainty, however, are likely to hinder the development of this type of framework[2]. As a result, it was suggested that instead of trying to develop a means for assigning valuations to individual chemicals, we should instead focus on ranking the differences between different types of chemicals, and use the output to prioritise regulatory efforts. In other words, develop an ordinal approach rather than a more cardinal one. Any budget on the value of chemical risk management will be subject to factors which are likely to change over time (income, scientific data on the scale of the problem, public understanding, etc.). As a result it may be more appropriate to focus on how to better prioritise those substances on which action should be taken than on trying to derive “accurate” valuations.

3.5 Question 5: Can a systematic means of describing or classifying the (potential) effects associated with different environmental risks be developed?

There was agreement that a classification system is important to contextualising the risks posed by different types of SVHCs. This then leads to questions over what type of classification system would be of most value? Does it need to go beyond a single species affected to the ecosystem level? And, if it should act at the ecosystem level, could an ecosystems services type framework be developed more specifically with such chemicals in mind in order to link the scientific case to human welfare endpoints? Is this a necessity to underpin monetary valuation?

The concept of ecosystems services, as a framework, was generally considered to be of value in providing a context to decision makers in terms of the value of the chemical and the value of the potential benefits from different types / levels of control. Its scientific basis should provide a robust way of thinking about the decision problem and thus help in setting the scope and information needed for decision making. It would also provide a valuable starting point for any valuation work, although this may also require linking human health endpoints (e.g. man via the environment) more clearly to impacts on the environment; in addition, the framework may need to be expanded to enable the transfer of effects from the environment to workers, professional users and consumers of chemicals where risk management would involve a move to substitutes.

2 The ability to create such a system implies that one has identified the full set of substances across which this budget should be spread; given the uncertainty surrounding the number of PBT and vPvB substances that will be identified following registration of all substances placed on the market at greater than 1 tonne per year per manufacturer, only guestimates of the numbers falling in this set can be made at this time. Furthermore, applying such a system would also require questimates to be made on the numbers of substances falling into different classes in terms of their properties and use characteristics. Such guestimates have been made for the purposes of EU impact assessments, but they should be refined if they were to act as the basis for allocating a WTP budget to the level of individual substances.

Any elaboration of a more SVHC focused ecosystem services framework, however, should provide a more systematic basis for reflecting uncertainty (i.e. providing a scalar on uncertainty). In this respect, it should help focus decision makers on what uncertainties are important and what uncertainties may not be important to the end decision.

There was a note of caution though - it is very difficult to extrapolate the impact on, say *daphnia*, to the valuation of impacts through ecosystem services. As a result, in general it is going to be difficult to find the data that would be needed for many of the chemicals to really fill the "cells" in such a framework. Thus, what one may only be able to say is that "this is important and this exposure might happen", as a means of helping others understand potential impacts in a more systematic manner. Elsewhere, this "semi qualitative" approach has also been useful in the promotion of public engagement in decision making.

As for ecosystem services as a communication tool, it may be possible to standardise how it is used, based on the types of tools and principles applied as part of risk communication in other fields (e.g. the use of risk ladders).

Finally, it was asked whether it would be possible to take a "back-casting" approach – e.g. a form of ex post evaluation – to inform the development of a classification system (and potentially to inform on the allocation of an overall budget as discussed under Question 4 above). The thought here is that by looking at the past, we gain information on the potential magnitude of future impacts. The key issue identified with this approach is that it assumes that the chemicals that have already been regulated are good predictors of future impacts. This may not be the case, as those chemicals that have already been regulated may actually have been the most toxic and thus using them as a reference may actually over-predict damages for some classes of chemicals or result in a failure to recognise the importance of new classes of chemicals.

3.6 Question 6: Can the scientific case based on precaution be expressed in a manner that the public can understand so that reliable valuations of the risks and uncertainties associated with PBTs and vPvBs can be derived?

The importance of clearly communicating the benefits of precaution was recognised by all. This indicated the need for better communication of risk and uncertainty and what these imply in terms of the need for precaution. The starting point should be a systematic framework that deals with uncertainty including: lags between exposure and effects, substance decay rates, levels of risk, and the types and importance of scientific uncertainties. From this, it should be possible to develop a proper rationale for taking precautionary action.

It was suggested that the above should be driven partially by precautionary risk management but by also adopting a longer term perspective with regard to achieving environmental objectives, to ensure that there is a balance between costs and benefits. This type of approach involves prioritisation of those SVHC (either individual chemicals or groups of chemicals) that should be addressed first/or their uses that should be addressed first over those where the risks of waiting to take action are likely to be lower (and thus need not be subject to immediate or near term controls). Monitoring systems would then be put in place to assess both the benefits of having taken action, the extent to which environmental objectives have been met, the level of on-going concern for those uses/chemicals not yet controlled, and the costs to industry, businesses and consumers from the loss of the controlled uses/chemicals. In essence, over time, this type of framework would provide a means of assessing the acceptability of the trade-offs arising from the control, or not, of SVHCs.

Responding to this brought the discussions back to the issue of whether there are likely to be different values for controlling the risks associated with different chemicals. Most participants seemed to agree that there is no single value, but instead a scale of values where any given chemical's location on that scale depends on the type of risk and the probability of that risk occurring. Others felt that characteristics surrounding its use were also important and had to be taken into account.

These discussions then led back to the need for some form of classification system, and possibly for a means of grouping chemicals overlaid on top of this. The classification system could then act as a means of benchmarking chemicals, using the outputs of WTP or other studies to establish benchmark valuations. Care would need to be taken in developing such a system to ensure that benchmark values could be robustly applied to chemicals within a group, even though they may have different characteristics in terms of fate, exposure and use and significant variations across other properties. This type of grouping could also provide a basis for cost-effectiveness analysis and the use of tipping points, e.g. if there is an exceedance of a particular threshold for either the group or for an individual chemical.

Alongside such a system, however, is some means of recognising that people may value the continued availability of some chemicals more than others (i.e. the significance of the economic and social welfare trade-offs involved in undertaking control or allowing continued use).

3.7 Question 7: Can and should chemicals be analysed singly or as a chemical group with similar effects?

The grouping of chemicals was a theme returned to several times as being important to the future regulation of chemicals. Although the discussions regarding valuation were focused more on grouping in terms of chemical properties, it was also suggested at this point that we may wish to group in terms of mode of effect, for example, grouping on the basis of endocrine disruption (which would capture a wide range of substances including pharmaceutical chemicals in addition to industrial chemicals); alternatively, one may wish to focus on grouping in terms of substances that deliver similar functions (e.g. flame retardants) to ensure that the economic trade-offs of regulating individual substances within the group vis a vis the impacts of adopting the alternatives are clearly understood.

There was general consensus that, whatever approaches are developed, they meet the needs of the different parties involved in decision making, e.g. they meet the needs of the SEAC when talking about REACH and the needs of Defra and the Environment Agency when referring to the WFD. This suggests that in the short term it may be necessary to analyse chemicals one by one, although the longer term goal may be to consider moving to a more group based approach, or one which better considered the synergistic (an antagonistic) effects of chemicals when present in mixtures.

3.8 Question 8: What are the implications of the issues presented above for assessing the environmental benefits of controls on PBTs in the short term? Are the proposed approaches fit for purpose? What do we need in the longer term?

Two key messages from the above discussions are that scientific uncertainty and a lack of scientific and other data may mean that we will never have all of the information required to prepare detailed economic analyses of costs and benefits. However, decision makers still need to make decisions. Against this background, the plenary discussions ended by considering what the implications of this and other points from the earlier discussions were for the future assessment of the benefits of precautionary controls on PBTs and vPvBs. The key "dos and don'ts" stemming from this discussion are:

- Don't put all of your eggs in one basket!
- Don't adopt different approaches for different regulatory regimes – a framework that ensures consistent approaches across REACH, the WFD and the IED is required to ensure coherent decision making.
- Look further into the risk communication literature and the insurance literature; in the case of the latter, this should be focused on the proportionality of valuations to avoid a risk or to the magnitude of that risk. For example, it may be possible to compare the health and environmental risks due to chemicals to other risks for which insurance *premia* have already been calculated. This would enable calculation of the premium attached to avoiding such risks, which could in turn act as a form of validation for any valuations derived through other approaches.
- Unpick what underlies the RCR with the aim of providing better information to decision makers on the nature of the potential risks, exposures, persistence in the environment, etc.
- Develop a systematic framework that helps structure preferences in the context of precautionary control towards uncertain impacts and which provides a basis for benchmarking/characterising substances and for developing "risk premiums".
- Examine the role of persistence and bioaccumulation as a driver of individuals' WTP for regulatory control of a chemical where there is no toxicity, but let toxicity be the driver where this is also a factor.
- Ensure that there is a consideration of the factors that may affect the risks of taking and not taking action: lags between emissions and effects, lags between taking action and gaining benefits, and the short and longer term implications for industry and society more generally (professional users and consumers) in terms of increased costs, lost innovation, etc. from taking precautionary action.

3.9 Where next?

3.9.1 A Research agenda

As indicated above, the discussions highlighted a series of areas for future research. These can be summarised as:

1) Research aimed at better understanding people's preferences towards the risks and uncertainty presented by PBTs and vPvBs using stated preferences methods. This should explore what underlies people's perceptions of the risks posed by such chemicals, whether

their attitudes and preferences towards these risks vary depending on different properties or characteristics of the substances and their use, how best to communicate such risks, and thus what approaches are the most appropriate for eliciting relevant valuations.

2) Research into the development of a classification system for PBTs and vPvBs (and potentially also including CMR substances given the overlaps that exist) that would enable a link between science, risk and economics to be established. For example, research is needed on *how to link* impact assessments, valuations of impacts, and (precautionary) decision-making. Exploring peoples' risk preferences and attitudes with regard to impacts from PBTs and vPvBs is not independent of a proper understanding of these risks. So far, very little is known about the relationship between environmental concentrations of a PBT or a vPvB and "impacts". Thus, exploring these relationships is a highly relevant challenge that is prior to any valuation of impacts. In addition, the outcomes of valuation studies have to be 'translated' into risk management strategies for PBTs and vPvBs. How this could, or should, be done is still highly unclear and requires further conceptual, interdisciplinary research.

3) Building on the research identified under point 2 above, there should be further exploration of the potential for developing a hazardous substances specific framework for describing potential impacts in terms of "ecosystem services". This needs to take into account the quantity and quality of the information likely to be available, as well as the potential need to incorporate wider human health considerations associated with shifts to substitutes (for such a framework to be truly of value under both WFD and REACH).

4) Further research should be carried out on the ability to capture people's valuation for precaution using stated preferences techniques, but this should also be accompanied by some more imaginative consideration of the use of revealed preferences methods, including work that draws more on the insurance literature. A key consideration should be whether or not such valuations reflect WTP to reduce the presence of a given substance of very high concern or rather whether it reflects a total budget for the control of such substances. This work could include the development of case studies using different methods, to identify what works and what does not work, and to test for convergence.

5) If robust valuations for precautionary action can be developed, then there may be merit in undertaking research into whether and how best to group substances and then benchmark these different groups (and indeed sub-groups within these) for valuation purposes (i.e. using a modified form of benefit transfer). The aim here would be to try and develop an approach that would allow allocation of a total budget for regulatory action across substances, where this takes into account their properties, the scale of the potential risks, temporal aspects, etc.

3.9.2 Next steps

The plenary ended with a brief discussion of what actions could be taken to help ensure that the types of research identified during the plenary discussions were carried out. Two initiatives were proposed:

- The first was the establishment of a network under the EC Co-operation in Science and Technology (COST) framework, with the aim of improving the sharing of information between the Europe-wide set of organisations already undertaking the type of research described above in a coordinated manner. The RSC volunteered to help organise such a bid over the next 6 months. Any bid should include not just risk assessors and economists, but also social scientists with a background in the fields of risk perception and risk communicaton.

- The second initiative involved approaching the EU chemicals, metals and pharmaceuticals industries with a set of proposals aimed at delivering elements of the above research suggestions. This could take the form of collaboration across associations or may even include approaches to individual companies, who may have significant vested interests in understanding the implications of the research results for their operations. Public authorities may wish to also contribute to such a research programme, e.g. to fund those elements not picked up by the private sector or to ensure that funding was sufficient to enable the results to be applicable at the EU and cross-regulation levels.

Annex 1 – List of Participants

Meg Postle (RPA)

Marco Camboni (RPA)

Steve Lipworth (RSC)

Chiara Dempsey (RSC)

David Taylor (RSC)

Stavros Georgiou (HSE)

Bill Watts (EA)

Jonathan Fisher (EA)

Roy Brouwer (Free University Amsterdam)

Sarah Bogaert (ARCADIS Belgium)

Silke Gabbert, (Wageningen University)

Steve Dungey (EA)

Matt Hallam (EA)

Nick Cartwright (EA)

Hans-Christian Stolzenberg, (Umweltbundesamt)

Susannah Mourato (LSE)

Mark Scrimshaw (Brunel University)

Gera Troisi (Brunel University)

Mike Holland, (EMRC)

Richard Dubourg (ECHA)

Kalle Kivela (ECHA)

Allan Provins (EFTEC)

Simon Scanlan (DEFRA)

Patrice Mongelard (DEFRA)

Marilena Pollicino (DEFRA)

Karen Thiele (Umweltbundesamt)

Oliver Warwick (Peter Fisk Associates)

Mark Owen (RSPB)

Michael Zand (HSE)

Arthur Thornton (Atkins)

Annex 2 - Workshop Agenda

10:00 Welcome & Coffee

10:20 Introduction: Socioeconomic Valuation of Hazardous Chemicals Control – State of the Art and Future Prospects (Bill Watts)

10:35 The nature of the environmental threat from PBTs: the science perspective (Gera Troisi/Mark Scrimshaw)

11:00 Guiding decision making on the authorisation of PBT and vPvB chemicals under REACH: A stock pollution approach (Silke Gabbert)

11:25 Economic valuation of environmental impacts in socioeconomic analysis under REACH: Possibilities and limitations (Sarah Bogaert)

11:50 Willingness to pay for the combined effect of uncertain environmental and human health risks: the case of micropollutants in Switzerland (Roy Brouwer)

12:10 Economic benefits of controlling PBT/vPvB substances: Two case studies (Susana Mourato/Stavros Georgiou)

12:50 Socioeconomic Valuation of Hazardous Chemicals Control: Issues, Challenges and questions for Discussion (Meg Postle)

13:15 Lunch

14:00 Plenary Discussion

16:45 Conclusion and Follow up

17:00 End

Annex 3 - Presentations

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Socioeconomic Valuation of Hazardous Chemicals Control – State of the Art and Future Prospects

Chemistry Centre, Royal Society of Chemistry, Burlington House, 6 September

Bill Watts, Environment Agency

Environment Agency

A joint workshop mounted by

- Royal Society of Chemistry
- UK Chemical Stakeholder Forum
- Environment Agency
- Health and Safety Executive

Environment Agency

Expectations for the day

- Summarise the state of the art of the valuation of hazardous chemical effect; specifically PBTS
- Meg Postle will act as a rapporteur and produce a report for other (notably UKSF) and quite possibly, follow up forums.
- Identify opportunities for research collaboration on the topic.

Environment Agency

Valuing the Benefits of Hazardous Chemical Management

- This workshop is not about policy reform or the validity of the Precautionary principle
- It is about information relevant to all the areas where a regulator seeks to manage Hazardous Chemical emissions and deposition.
- It cuts across the REACH, WFD, IED and other policy domains.

Environment Agency

Policy context is important though

- "REACH is based on the principle that it is for industry *to ensure that they manufacture, place on the market or use such substances that do not adversely affect human health or the environment. Its provisions are underpinned by the precautionary principle* (Article 1(3))".
- The Precautionary principle lies at the heart of much Community Environmental Regulation

Environment Agency

.... So what?

- Precautionary regulation affects companies (loss of market, consequent changes to production processes and the costs of abatement technologies) and
- Wider society (passed-on costs, loss of useful substances and substitution by substances which may be equally harmful)
- Yet there is MP2 no apparent countervailing and quantified measure of benefit

Environment Agency

An idea of scale

Predicted Numbers of Substances with Hazardous Properties by Tonnage Band			
Note: Hazardous, extends beyond PBTs; including carcinogens, mutagens, reproductive toxins.			
Source: RPA 2006, Impact Assessment of implementing GHS (Globally Harmonised System)			
<10 tonnes	19,200 substances	4,435 (no data)	6,720 (poor data)
10-100 tonnes	4,977 substances	1,150 (no data)	1,742 (poor data)
100-1,000 tonnes	2,461 substances	568 (no data)	861 (poor data)
>1,000 tonnes	2,704 substances	530 (no data)	946 (poor data)
Total	29,342 substances	6,683 (no data)	10,270 (poor data)

Environment Agency

.... So what and more..

- If improperly handled information about chemical risks can yield destructive results; over-regulation and economic damage.
- There are the risk of false positives (unnecessary bans) and false negatives (chemicals which should be banned and are not)
- Moreover there is the question of the best point of regulatory intervention; should we eliminate Triclosan at the point of use or take it out of sewage waste water?

Environment Agency

What do we lose by letting PBT's accumulate?

- We lose options; the value and range of choice are reduced as these chemicals accumulate. At some point we may encounter, tipping points where there is no going back.
- We are exposed to uncertainties, which may be adverse and increase as these chemicals accumulate into the environment
- There may be adverse interactions between these chemicals as they accumulate in the environment

Environment Agency

The aggregate of small decisions is a big decision

- The problem of course is the classic one of making choices at the margin
- We assess chemicals one by one and not as a group
- One by one analysis makes it difficult to get at "system integrity" effects
- Individually the effect of emissions of a chemical may be trivial, but collectively profound

Environment Agency

We should worry about PBTs

- They are Persistent and accumulate… and the effects are often unclear; depends on pathways, transport, storage medium and time
- The natural capital effect; should the reduction of assimilative capacity be added to the sum of direct and indirect use and non use values?
- We may wish to appraise and regulate PBTs as a collective, grouped by ecosystem effect, rather than singly.
- PBTs can damage people and the environment, even when their risks are low according to the traditional exposure/effect comparison approach.

Environment Agency

Things to think about (1)

- Valuing hazardous chemicals' effects requires an understanding of their effect on the welfare of the community. (Interpreting scientific data on effect in a way that people understand and value is essential.)
- Reuse valuation data for all regulatory regimes, REACH, WFD or Industrial Emissions Directive. The science relates to the chemical, not the regulatory process.

Environment Agency

Things to think about (2)

- Valuation of effect, chemical by chemical may neither yield usable results or be meaningful. (Grouping of chemicals may be needed to value effect; but how to group, welfare end point?)
- But also people value the avoidance of the risk. There is likely to be an insurance premium which the public will be willing pay to mitigate the "risk".

Environment Agency

Things to think about (3)

- Re-assess the use of incomplete scientific data to inform the public's assessment of potential risks from hazardous chemicals. Be systematic in describing effect and use value transfer where we can, but not be shy of new primary valuation.
- Issue of which is the most appropriate measure of benefit Willingness to Pay (WTP) or Willingness to Accept, or something else?

Environment Agency

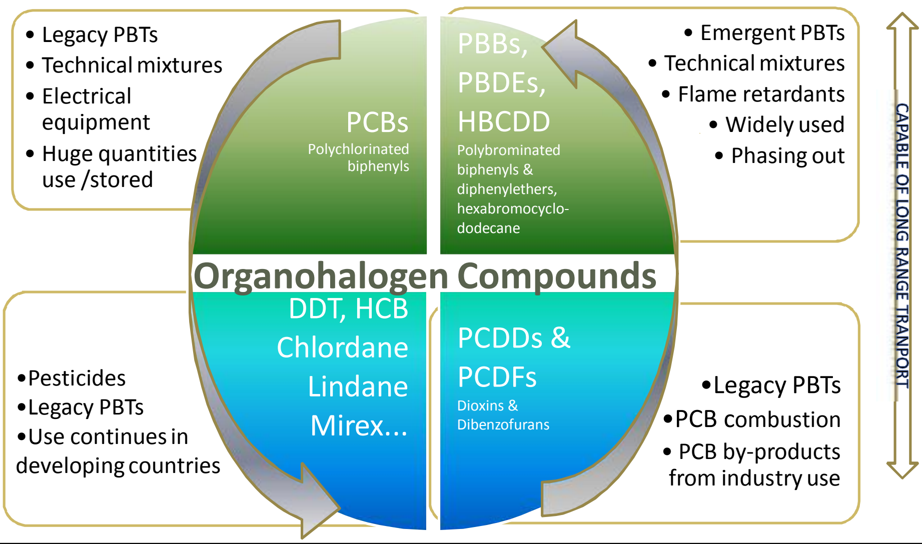
PBTs: Exposure & Health Effects
…the Science behind the Threat"

- **Properties of PBTs**
- **Focus on Organohalogen Compounds:**
  - Wildlife Exposure & Population Impacts
  - Human Exposure & Health Hazards
- **Some emergent PBTs: Exposure & Health hazards**
- **Risk Management**
- **Summary & Points for Discussion**

Dr Gera Troisi
School of Engineering & Design
Kingston Lane, Uxbridge UB8 3PH. U.K.
gera.troisi@brunel.ac.uk
Brunel UNIVERSITY LONDON

Focus on Organohalogens:

- Effects well-characterised in wild mammals - relevance to humans (sentinel species)
- EDCs - important for population-level impacts
- Structurally similar to emergent PBTs providing weight of evidence for concern



PBTs:

Persistent

- Poorly metabolised and resist to environmental degradation

⇒ **Stable** in environment & biota

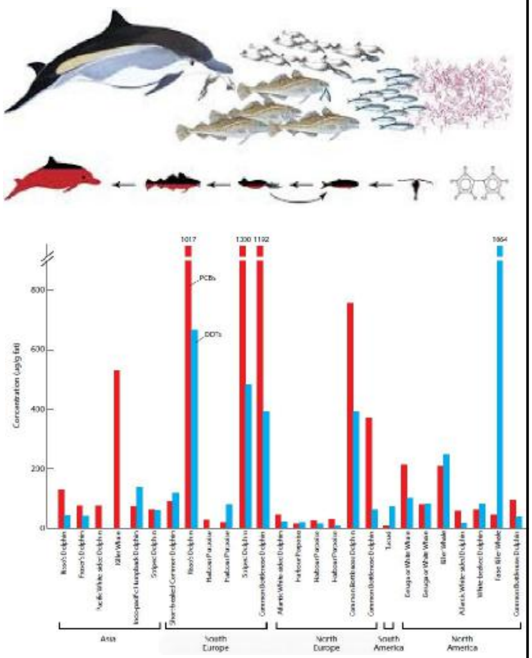
Bioaccumulative

- Lipophilic (high K_{ow}). Concentrate in organic matter & fats (tissue lipids)
- Persistent + Bioaccumulative => **Biomagnify** in food chains

⇒PBTs concentrations magnify from producers to top predators

⇒Highest burdens in adult males

Almost impossible to control once released. Easily dispersed - now ubiquitous even at distant locations from point sources.



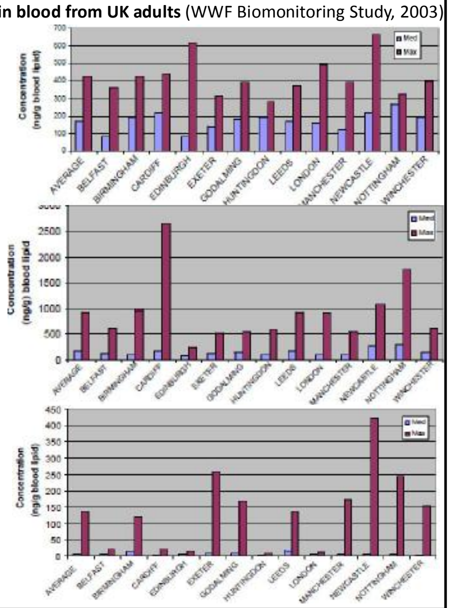
Mean µg/g (l.w.) PCBs & DDT in male Delphinids
(UNEP EDCs Report 2012)

PBTs: Human Exposure

Food/feed group	N	LB/UB	Mean
Expressed on fat basis			
Meat and meat products ruminants	132	LB	3.97
		UB	4.64
Meat and meat products poultry	111	LB	2.48
		UB	2.88
Meat and meat products pigs	181	LB	3.05
		UB	3.69
Liver and products terrestrial animals	62	LB	2.00
		UB	2.10
Raw milk and dairy products incl butter	5,640	LB	9.14
		UB	9.20
Hen eggs and egg products	721	LB	16.3
		UB	16.7
Fat ruminants	143	LB	8.69
		UB	8.71
Fat poultry	53	LB	2.85
		UB	2.85
Fat pigs	40	LB	0.98
		UB	1.04
Vegetable oils and fats	51	LB	3.02
		UB	3.21
Marine oils	40	LB	117
		UB	117
Infant and baby food without fish meat	16	LB	0.36
		UB	0.37
Infant and baby food containing fish meat	16	LB	10.9
		UB	10.9

Mean ΣPCB levels (µg/kg) in E.U. food (EFSA , 2010)

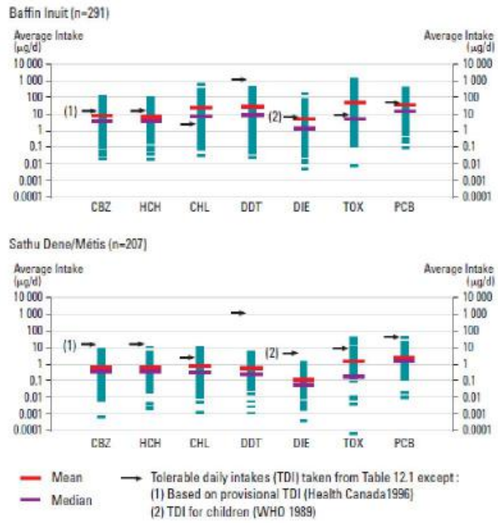
Mean & median concentrations of PCBs, Organochlorine pesticides and PBDEs in blood from UK adults (WWF Biomonitoring Study, 2003)



- Main source of non-occupational exposure is diet, household & personal care products, computer use and indoor air
- Once ingested, accumulate in body fats
- This can mean a life-time of exposure (DDT 50yrs & PCBs 75yrs)

High-end Exposure: *Communities "at Risk"*

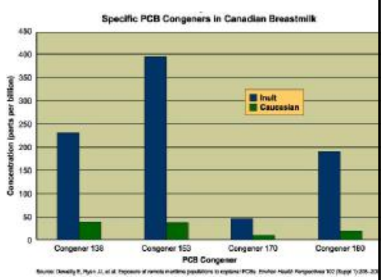
- Despite controls on PCBs and OC pesticides, still a constant influx to Arctic Ecosystem sustaining human exposure
- Dietary exposures of PCBs and OC pesticides can **exceed** Tolerable Daily Intakes (TDIs) due to high consumption of fish and marine mammals



Organochlorine intake from traditional food consumed by indigenous women in Canadian Arctic (AMAP, 1998)

Developmental Exposure in Mammals

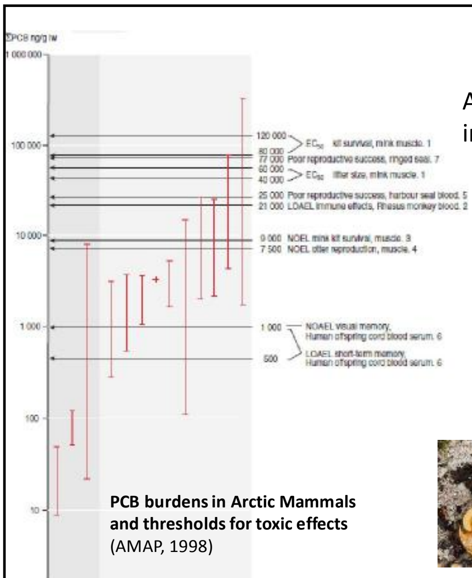
- Due to properties of PBTs, there is potential for significant transgenerational peri-natal exposure:
  - Can pass placental barrier into foetus
  - PBT mobilised from fat stores to breast milk
- Mammals are most sensitive to chemicals peri-natally, especially EDCs – critically period of cell differentiation & organogenesis:
  - Detox & excretion systems not fully developed
  - Body dilution factor much smaller
  - adverse effects occur concurrently & further become evident later in adult life
- In Arctic communities, observed breast milk and cord blood PBT concentrations are reported be a cause for concern (AMAP, 1998). Suspected cause of high first pup mortality in seals.



Toxic Effects in Wildlife

A range of adverse effects reported in invertebrate & vertebrate wildlife, including;

- Egg-shell thinning in raptors
- Uterine deformities & sterility in seals
- Birth defects in panthers & alligators
- Immunological effects on dolphins
- Cancer in beluga whales
- Shell thickening in oysters
- Neurological effects in birds
- Imposex in dogwhelks



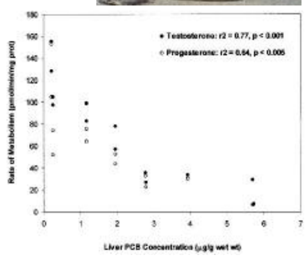
PCB burdens in Arctic Mammals and thresholds for toxic effects (AMAP, 1998)

Reproductive effects in Wild Mammals

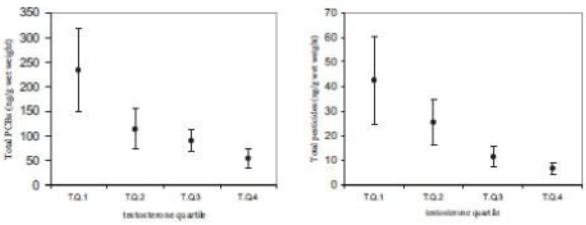
Reduced reproductive success and population impacts due to organohalogen exposure. Reproductive failure shown by controlled dosing of captive seals & mink

Further evidence from bio-monitoring & *in vitro* studies indicate endocrine disruptive mechanisms:

- Disruption of sex hormone metabolism
- Altered adult plasma sex (P, T, E2) and thyroid hormone levels (polar bears, porpoises, seals, otters)



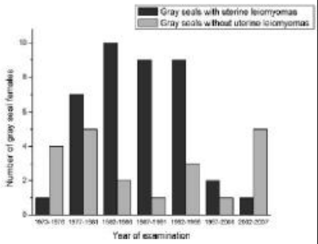
Hepatic metabolism of sex hormones versus PCB in North Sea Harbour Seals (Troisi & Mason, 2000)



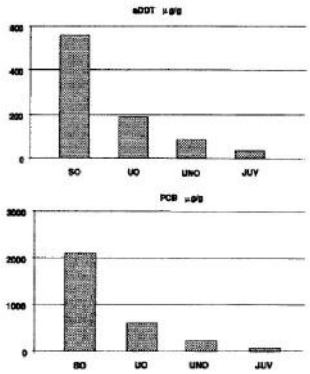
PCB and pesticide levels versus mean plasma T in male Polar Bears (Svalbard, Norway). Mean ages T.Q. 1–4 are 1, 6, 10, 15 yrs, respectively (Oskam et al.2003).

Pathological deformities in Seals

- **Uterine fibroids, uterine tubal stenoses & occlusions** leading to **infertility**. Incidence of deformities associated with blubber PCB & DDT burdens = **population declines** in 1970-1990 due to 50% sterile females. Bothnian Bay population growth rate down 50% between 1988 & 2002 (Härkönen et al. 1998)
- Reproductive failure linked to OC exposure. Evidence from controlled feeding studies with captive seals & mink. *In vitro* studies revealed **endocrine disruptive toxic mechanisms** mediated by PCB & DDE metabolites.



Incidence of uterine leiomyomas in seals aged 22-41yrs (Bredhult et al, 2008)



Blubber PCB & DDT burdens (l.wt) **in Baltic Grey Seals** (starved adult females with occluded uteri (SO), unstarved with occluded uteri (UO); unstarved with normal uteri (UNO), juveniles (JUV) (Olsson et al 1994)

PBTs: Human Health Effects

- Adverse effects on humans include:
  - Neurological effects
  - Thyroid dysfunction
  - Reproductive & developmental effects
  - Thyroid dysfunction and thyroid cancer
  - Infertility
  - Congenital (e.g. chryptochordism) & pathological deformities of reproductive tract, including cancers
- Most of the above are mediated via **endocrine disruptive** toxic mechanisms
- Validated methods to test EDCs are not yet available for a range of human health effects
- Evidence obtained from:
  - Mechanistic studies
  - Toxicity testing of lab animals
  - poisoning incidents, accidental contamination/spills
  - Epidemiological evidence
  - Effects in sentinel species
- Quantity & quality of data is variable, often lacking.
- Heavy reliance on expert judgement, weight of evidence approach.

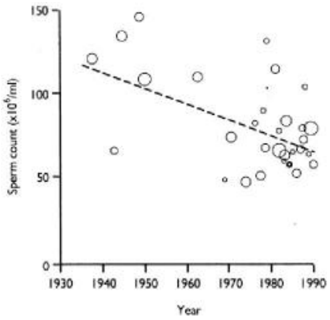
Finding causality of health effects in a Chemical Cocktail

- Centre for Disease Control (CDC) National Biomonitoring Program reports the average American carries 116 toxic chemicals (2001-2002). Another study quotes over 200 chemicals in cord blood in the US (EWG, 2005).
- PBTs occur in technical congener mixtures within a cocktail environmental chemicals. Difficult to decipher net effect(s) of single chemical/groups on individuals & populations, especially if they are endocrine disruptors. Metabolites also a problem.
- Regulatory triggers (e.g. "tolerable limits") are mostly set for individual chemicals - do not accommodate the nature of environmental exposure.
- More uncertainty

Infertility in Men

- Increasing trend in infertility, affects 2.1 million couples in US alone.
- Falling sperm counts contributing factor. Suspected cause is EDC exposure.

- **Some epidemiological evidence:**
  - Urinary **alachlor** level correlated with poor semen quality in US men (Swan, 2006).
  - Blood **PCBs & DDE** levels associated with poor sperm quality in Northern Europe (Toft et al, 2006).
  - Peri-natal **dioxin** exposure associated with poor semen quality in Seveso Disaster victims (Mocarelli et al, 2011)



Linear regression of mean sperm density in men reported in 61 publications weighted according to sample size
(Carlsen et al, 1992)

Pathological Disorders in Men

Some epidemiological evidence:

Un-descended testes (crytochordism)

– Higher OC levels in cryptorchordid boys than control subjects (Hosie et al. 2000).

– Positive correlation between mother's breast milk PBDE level and incidence of cryptorchidism in sons (Main et al. 2007)

Testicular cancer

– Mothers of men with testicular cancer in Sweden found to have significantly higher PCB, PBDEs and HCB levels than control mothers (DDE levels did NOT differ; Hardell et al. 2006).

Pathological Disorders in Women

Uterine fibroids (leiomyomata)

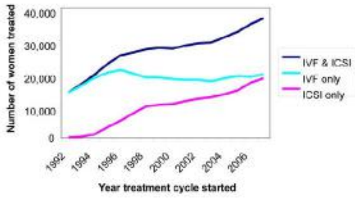
- Affects 20-25% of pre-menopausal women. Leads to infertility.
- Incidence of fibroids positively associated with PCB exposure in women eating fish from Great Lakes (Lambertino et al, 2011).
- Fibroids observed in **Baltic seals** with elevated organohalogen burdens**.**
- PCBs, DDE & their metabolites affect human & seal uterine myocyte proliferation *in vitro* (Backlin et al 2003; Bedhult et al 2007)

Endometriosis

- Affects >1.5 million women in UK. Present in nearly 50% of infertile women.
- Porpora et al (2009) found PCB & DDE exposure positively correlated with **endometriosis** incidence but another study found **only** HCH levels correlated (Buck Louis et al 2013)

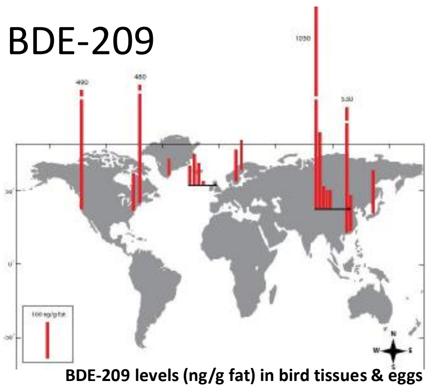
Infertility in Women

- Increasing numbers of women undergoing IVF costing in UK. IVF cost to NHS is currently £400 million/year!
- **Epidemiological Evidence:**
  - Harley et al. (2010) reported serum PBDE levels were correlated with longer time to pregnancy.
  - A study of women undergoing IVF found that individuals with BDE 153 present in their follicular fluid had significantly increased chance of failed embryo implantation (Johnson et al. 2012)

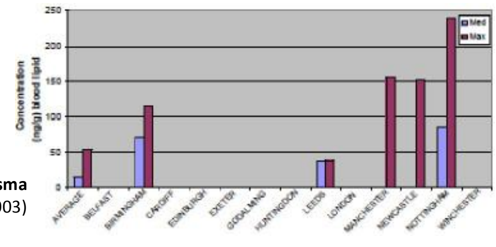


Flame retardants still in use: BDE-209

- BDE-209 testing on mice showed developmental exposure induced sperm abnormality, oxidative stress, DNA damage & testicular deformity (Tseng et al 2013)
- In European Men: evidence of inverse association between plasma testosterone, and plasma from DBE209 from exposure to house dust (Johnson et al. 2013).
- Median BDE-209 in Norwegian breast milk = **0.32ng/g** (l.wt) (Thomsen et al 2010).
- BDE-209 in blood sampled from UK adults < **240ng/g** l.wt (WWF, 2003)

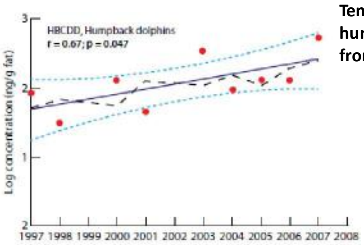


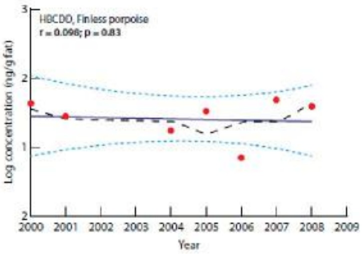
BDE-209 levels (ng/g fat) in bird tissues & eggs
(Chen & Hale 2010)



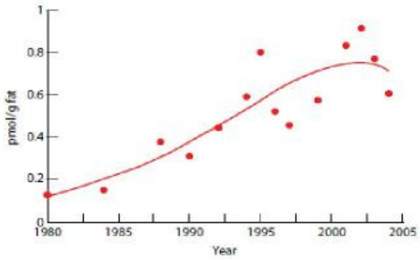
Median & maximum BDE-209 levels in Human plasma
(WWF UK Biomonitoring Study, 2003)

Flame retardants still in use: Hexabromocyclododecane (HBCDD)





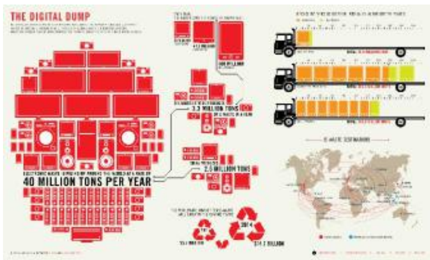
Temporal trends in HBCDD burdens in blubber of Indo-Pacific humpback dolphins (1997-2007) and finless porpoises (2000-08) from Hong Kong Harbour (UNEP (2012) EDC Report, 2012)



Temporal trends of HBCDD concentrations in mothers' milk in Stockholm, Sweden (1980–2004) (Fängström et al., 2008)

HBCDD evidence for endocrine disruption? Johnson et al (2013) found significant alterations in between blood testosterone & binding proteins with plasma HBCDD exposure in men.

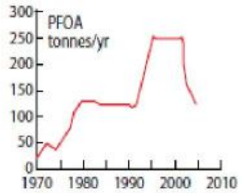
Flame retardants in E-waste



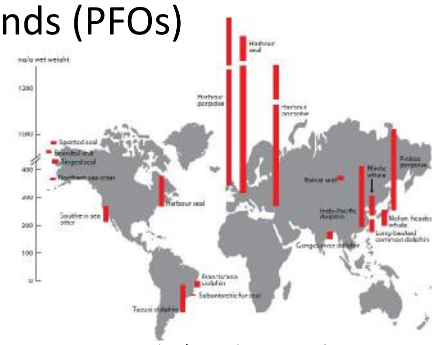
- E-waste is generated at **20-50 million tonnes per year** globally.
- In Europe e-waste generation increasing at 3-5% per year (3x faster than total waste stream)
- Estimated flame retardant concentrations in a small WEEE item (Morf et al 2005);
  - PentaBDE = 34 mg/kg
  - OctaBDE = 530 mg/kg
  - BDE-209 = 510 mg/kg
  - TBBPA = 1420 mg/kg
  - HBCDD = 17 mg/kg

- PBTs will enter environment from e-waste at crude recycling centres in developing countries
- Significant releases to susceptible communities less able to deal with health impacts (socially, economically & physiologically)

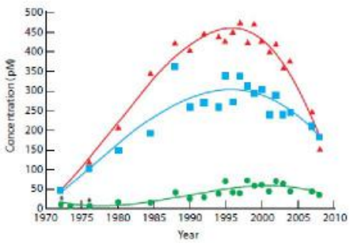
Emergent PBTs:
Perfluoro-octane compounds (PFOs)



Estimated maximum global emissions of PFOA
(Armitage et al, 2006)



PFOS burdens (ng/g w.wt) **in livers of marine mammals**
(UNEP EDC Report, 2012)



Trends in PFOS (▲), PFOA (■) & PFHxS (●) levels in Swedish mothers' milk; 1972-2008
(Sundström et al. 2011)

- Anti-stick, anti-statics (e.g. textiles, electronics).
- PFOs present in European food – possibility for exceedance of TDI for PFOS (150ng/kg b.w.) in EU
- Persist in human tissues (PFOA 29yr; PFOS 60yr).
- Breast milk & cord blood levels in Denmark of PFOS & PFOA: 33 & 11 and 5 & 4 ng/ml (Fei et al 2007) but highest burdens found in top predators.

PFOs: Health Effects (epidemiological evidence)

- Studies of families occupationally-associated with e-waste recycling in China, found maternal & peri-natal PFOA exposure predictive of adverse birth outcomes (premature delivery, low birth weight, stillbirths) and negatively associated with gestational age, birth length and APGAR scores (Wu et al. 2012).

- A similar study found correlations between PFOA and altered blood estradiol and testosterone levels, and oxidative homeostasis (Zhou et al 2013).

- Study of 506 employees at **perfluoro octanoic acid** (PFOA) manufacturer found negative association of PFOA with thyroxine levels (Olsen & Zobel, 2007).

- **Perfluoro octane sulfonate** (PFOS) exposure in women in US associated with higher incidence of **thyroid disease** (Melzer et al., 2010).

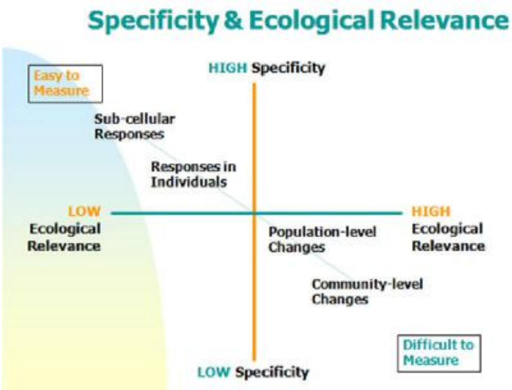
Emergent PBTs: Cyclic Methyl Siloxanes

D4 (octamethylcyclotetrasiloxane)
D5 (decamethylcyclopentasiloxane)
D6 (dodecamethylcyclohexasiloxane)

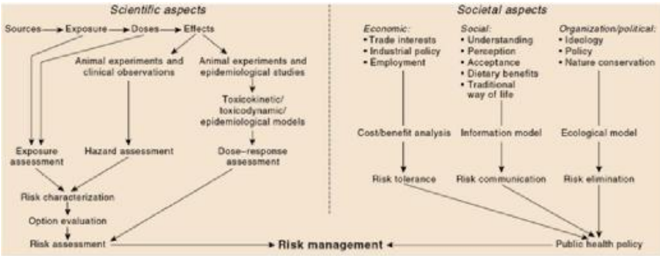
- Wide industrial application (thermally stable, inert, solvent carriers) from electronics, textiles and personal care products (cyclomethicones).
- **Human Exposure**: dermal and inhalation exposure route from PCP use. Daily D5 exposure from PCP use in US women estimated at 233 mg/day (Horii & Kannan, 2008). Hanssen et al. (2013) found no correlation between D4 blood levels and body cream use in pregnant Norwegian women - low levels observed (D4: 12.7ng/ml; D5 & D6 n.d.) concluding **low foetal exposure risk**.
- **Wildlife exposure:** High potential for bioaccumulation but no data available.
- **Evidence for toxicity:** limited evidence for some ecotoxic effects (Sousa et al 1995). Toxicity tests on rats found D5 caused uterine tumours, D4 caused inhibition of ovulation. Other lab animal tests indicate lung irritation & immuno-toxicity. Hormone receptor tests found D4 weakly estrogenic (Quinn et al. 2007).

Risk Management: Sources of Uncertainty

- Serious **paucity of data** for population-level exposure and effects from wildlife & humans - ethical reasons & resource intensive.
- Data on causality at higher levels of biological organisation difficult to decipher



Risk Management: Risk Perception



- Consumption of traditional foods has lead to "unacceptable" levels of human exposure in Arctic Inuit and breast milk contamination (AMAP, 1998)
- Scientists advise local health care providers to advise women of child-bearing age of exposure risks and consider reducing consumption of traditional foods
- BUT health & social (bonding) benefits of breast feeding perceived to **outweigh** risk
- Also other health (n-3 fatty acids, vitamins, trace elements), social & cultural benefits of consuming traditional foods also perceived to **outweigh** risk

Risk Communication

Royal College of Obstetricians and Gynaecologists

Bringing to life the best in women's health care

10. Opinion

Despite uncertainty surrounding the effects of common environmental chemicals, mothers should be made aware of the sources and routes of exposure, the potential risks to the fetus/baby and the important role that the mother can play in minimising her baby's chemical exposure. Such information should be conveyed routinely at infertility, antenatal and well woman clinics as well as via the media. In this way, women will be made aware of the uncertainties which will enable them to make informed choices regarding lifestyle changes which can be made to minimise environmental chemical exposure to their unborn child.

Scientific Impact Paper No. 37

May 2013

Chemical Exposures During Pregnancy: Dealing with Potential, but Unproven, Risks to Child Health

CIA Chemical Industries Association

CIA Press Release (June, 2013):

"..report clearly edging on side of precaution ... people should not be unnecessarily alarmed."

*"...**no definitive evidence that chemicals mentioned are associated with clear risks**.*

Summary & Points for Discussion

- Although many banned, tonnes are still in use with no options for safe disposal
- Now **ubiquitous,** persisting for decades in biota
- Exert **multiple toxic effects** via various modes of action, including **endocrine disruption**
- **Population-level impacts** observed in humans & wildlife
- **"Emergent" effects** in communities & Ecosystems suspected but difficult to establish
- Sources of **uncertainty** in Risk Management
  - **Causality** (exposure => effect) difficult to establish
  - Reliance on **extrapolated data**
  - **Interactive** effects of mixtures
- Major increases in **E-waste** = major source of brominated flame retardants
- Timely & accurate validation of suspected eco- & human effects for regulatory decisions is **not realistic** or **best practice**
- Better to exercise **precaution** and use saved resources to innovate **risk mitigation** options: disposal/ recycling / substitution

Guiding decision-making on the authorisation of PBT and vPvB chemicals under REACH: A stock pollution approach

Silke Gabbert
Department of Social Sciences
Environmental Economics and Natural Resources Group
Wageningen University (The Netherlands)

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Workshop "Socio-economic Valuation of Hazardous Chemicals Control", September 2013, Royal Society of Chemistry, London.

Overview

1. Policy background and objectives
2. Structure of the decision problem
3. A socio-economic model framework for decision-making on the authorisation of PBTs and vPvBs
4. First results and implications for decision-making
5. Proposed research agenda

1 Policy background and objectives

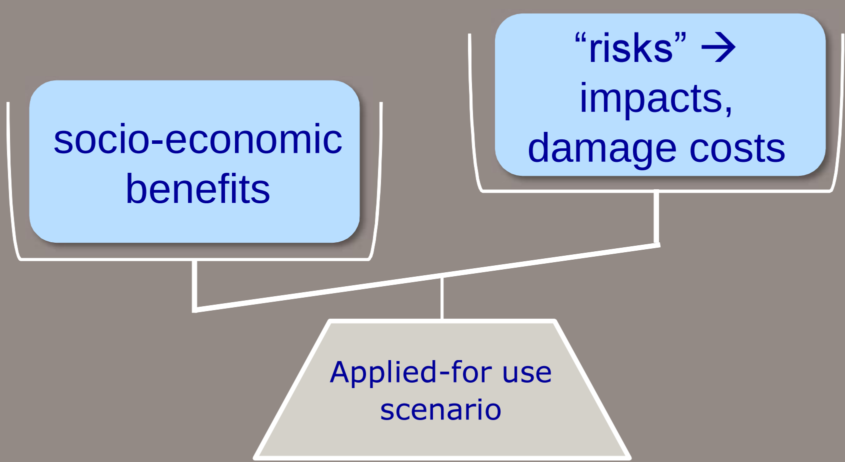
Authorisation

Adequate control route	Socio-economic route
See REACH, Art. 60, para 2	See REACH, Art. 60, para 3
NOT possible for PBTs and vPvBs because for these substances a threshold according to section 4 of Annex I cannot be determined	"[...] authorisation may only be granted if it is shown that the socio-economic benefits outweigh the risks to human health or the environment arising from the use of the substance if there are no alternative substances or technologies."

Application route for PBTs!

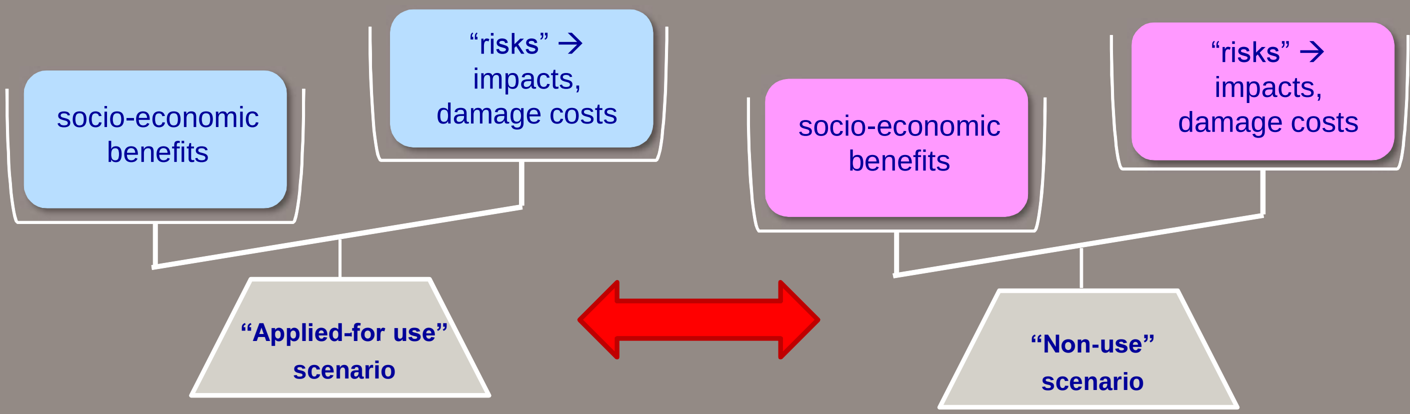
1 Policy background and objectives

Authorisation for a specific use of a substance can be granted if:



1 Policy background and objectives

Authorisation for a specific use of a substance can be granted if:



- PBT is removed without substitution
- PBT is removed but replaced by another PBT
- PBT is removed but replaced by a non-PBT

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1 Policy background and objectives

Main challenges:

1. Conceptual:
   - Structure of the decision-problem
   - Scenario definition
2. Methodological
   - Identification of suitable impact and benefit measures
   - Tools for balancing benefits against impacts/damages
   - Impact/benefit assessment
   - Monetary or non-monetary valuation of impacts?
3. Empirical:
   - Data/information needs
   - Research priorities

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1 Policy background and objectives

Objectives

- Develop a socio-economic model framework for structuring decision-making on the authorisation of PBTs and vPvBs
- Develop a toolkit that guides decision-makers on how to weigh benefits against impacts/costs of PBT use in an SEA
- Identify practical steps and research needs

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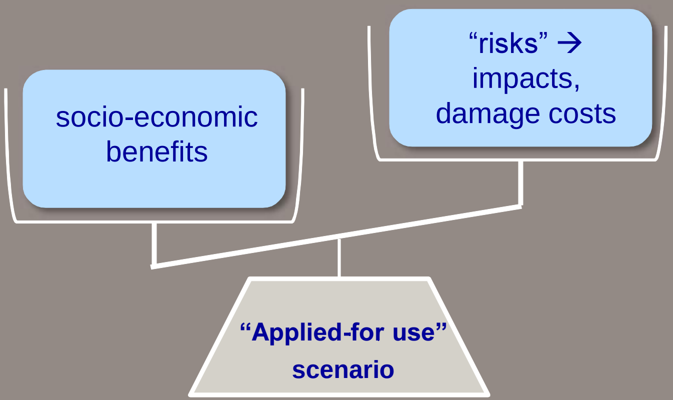
2 Structure of the decision problem



- We follow an analytical modelling approach that captures costs and benefits of an AFU and NU scenarios
- We adopt the hypothetical assumption that all impacts could be monetised

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2 Structure of the decision problem

- The use of a toxic, persistent chemical causes pollution (environmental concentration)
- With continuing emissions pollution increases over time
  → pollution stock *P*
- Relationship between the pollution stock and time
  → stock dynamics

$$\frac{\partial P}{\partial t} = m_t - \alpha P_t$$

m_t = emissions in period t

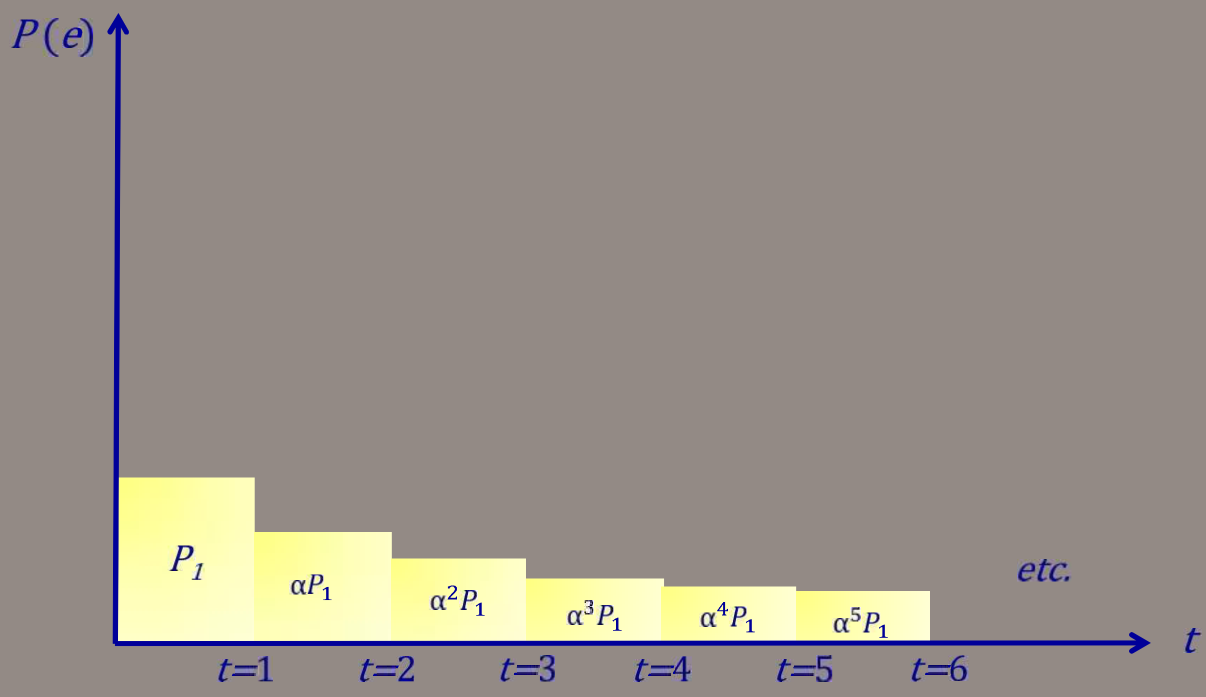
α = decay or degradation half-live

$$\Leftrightarrow \dot{P} = m_t - \alpha P_t$$

- The change of stock depends on emissions *m* at *t* and on the decay *α* of the substance

2 Structure of the decision problem

- **Graphical illustration of a stock pollution problem (discrete time):**



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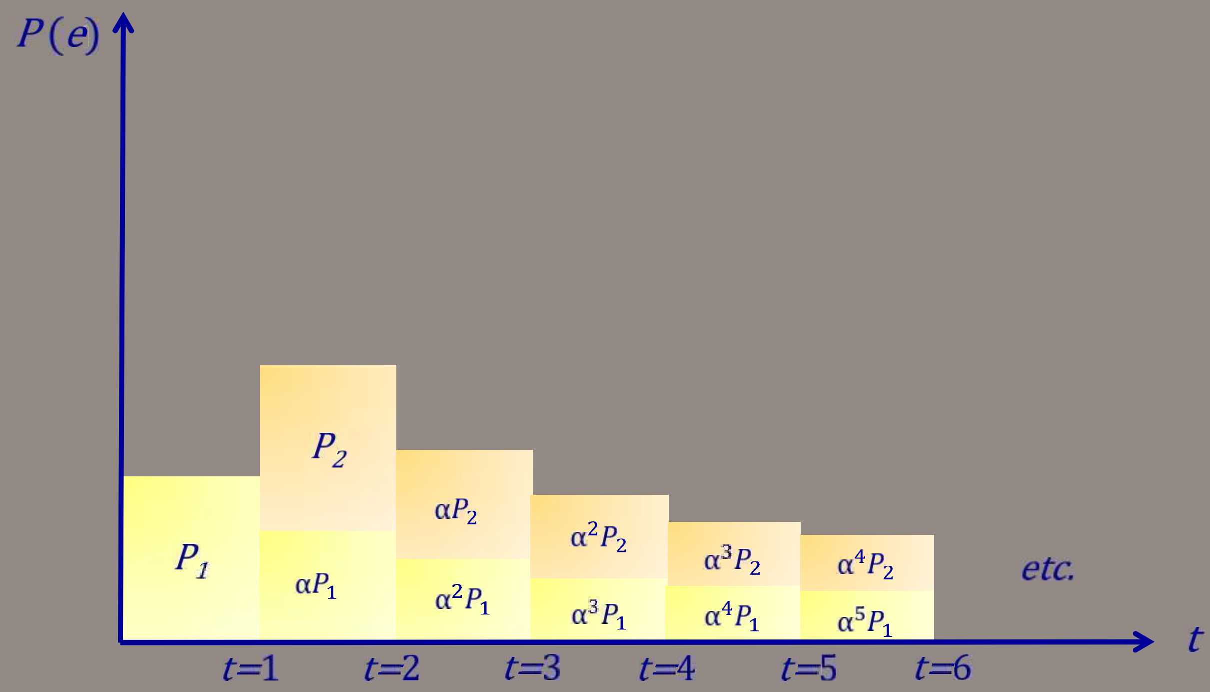

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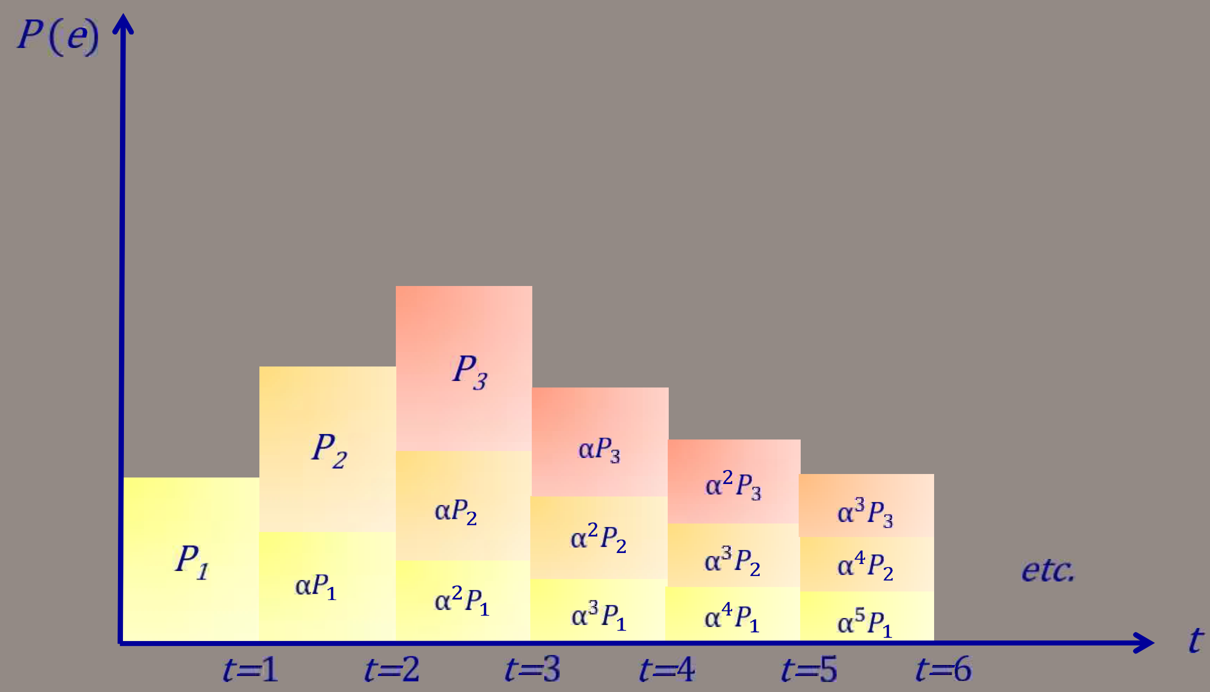

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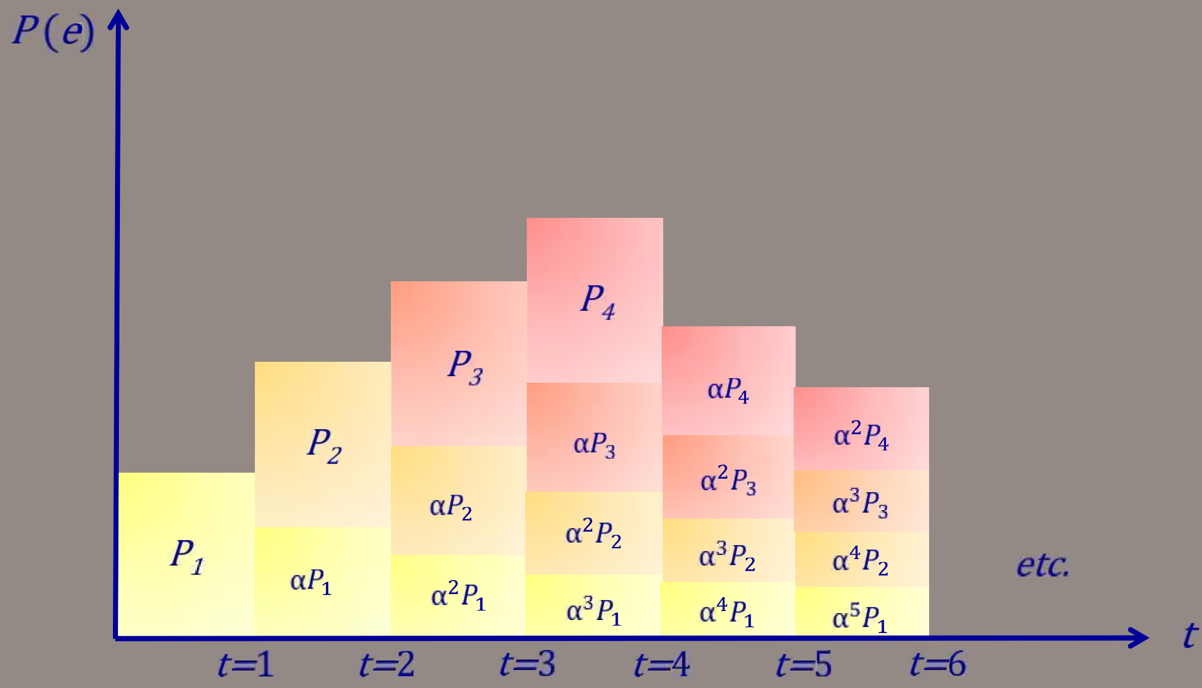

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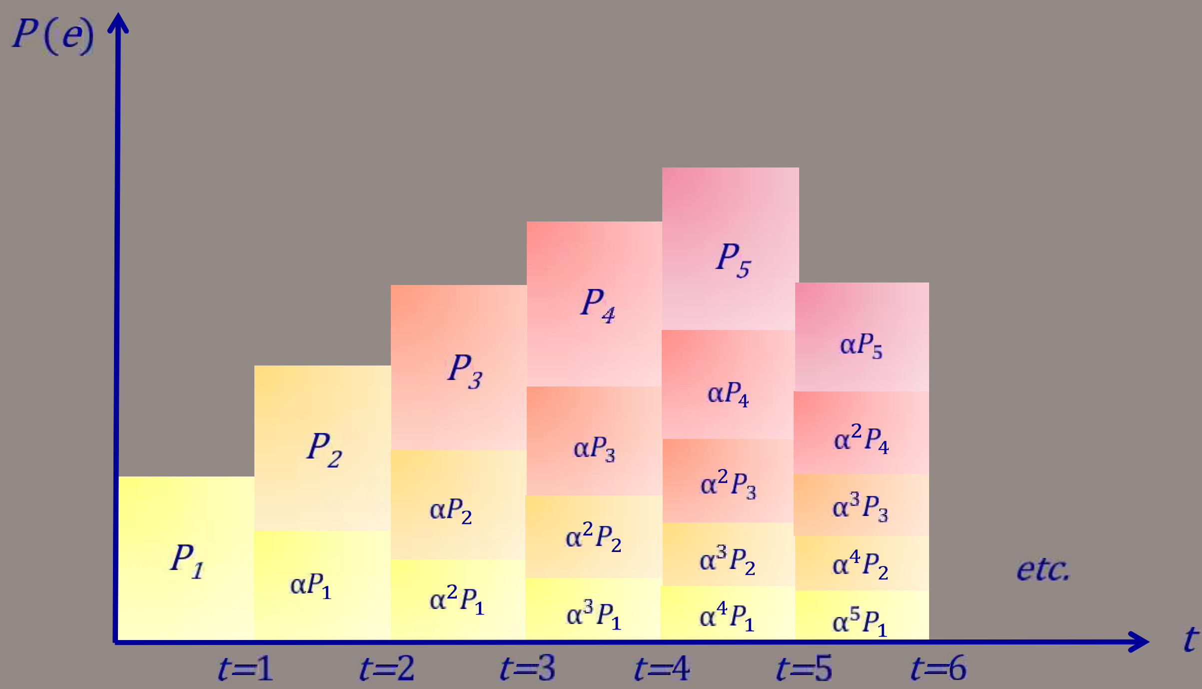

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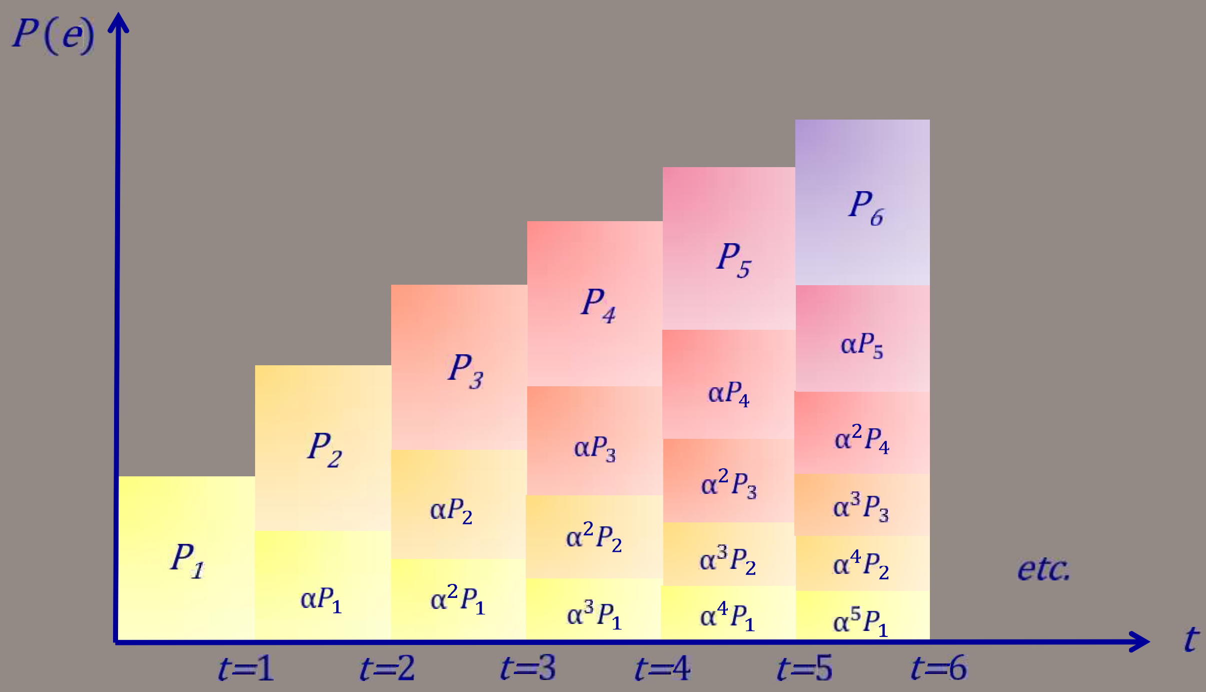

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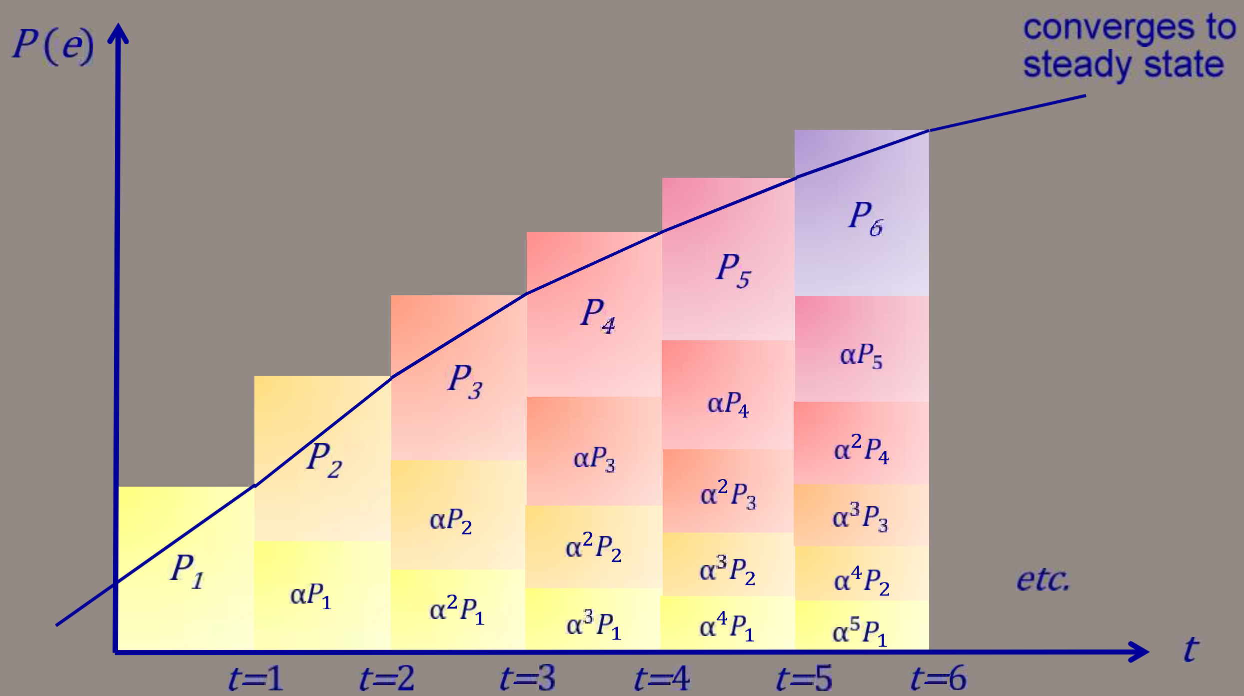
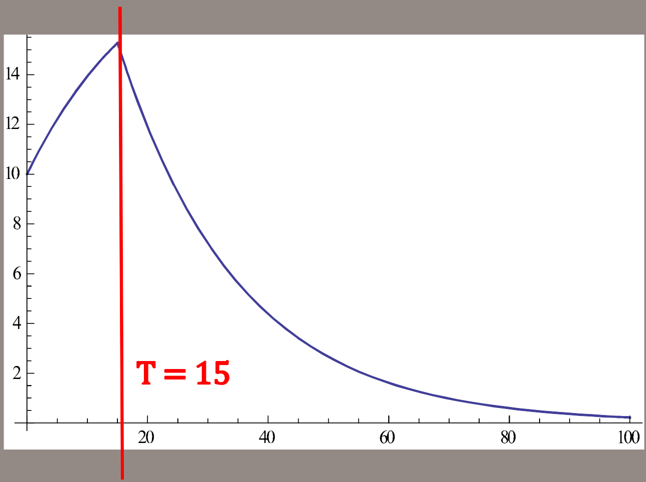


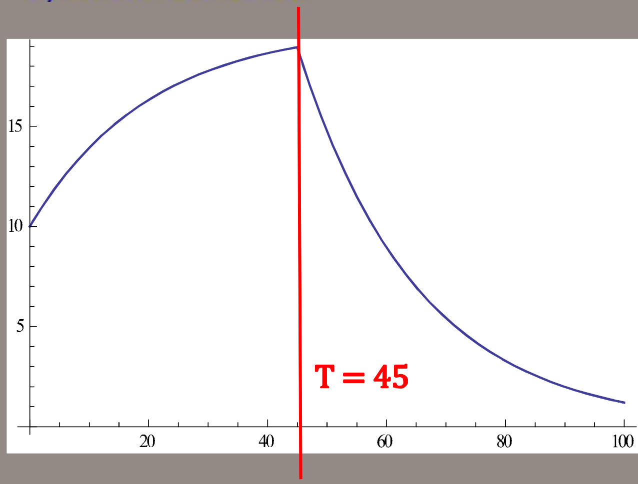
2 Structure of the decision problem

- Suppose that a chemical with decay-rate α is emitted with constant rates

a) Early removal



b) Late removal



- The pollution stock increases until emissions stop and decreases thereafter depending on α
- Even without further emissions pollution remains!

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2 Structure of the decision problem

Chemical *i*

a) Toxic
- Damage costs at *t* depend on emissions at *t*

b) Toxic and persistent
- Damage costs at *t* depend on the stream of emissions from previous periods and the decay of the chemical

- **If emissions are constant over time...**

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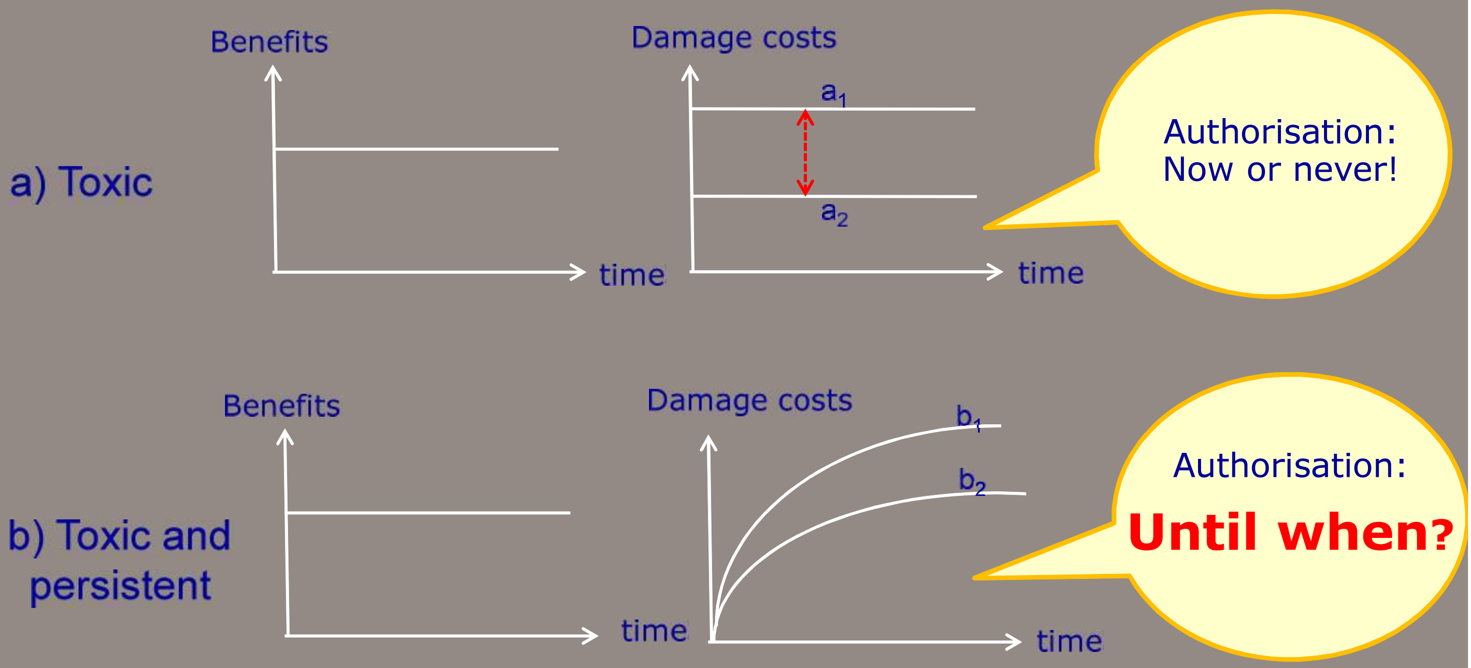
2 Structure of the decision problem



- **Authorisation of PBTs and vPvBs is an optimal timing problem!**

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3 A socio-economic model framework

- The model framework compares benefits with damage costs of any policy scenario (AFU, NU)
  - Monetary social benefits
    → profits from marketing the PBT + monetised social benefits (e.g. health improvements)
  - Monetised risks/negative impacts = damage costs
    → environmental damage costs
    → health damage costs
    → social damage costs
    → economic damage costs

$B(m)$

$x = release\ tonnage$

$D(P)$

$P = pollution$

$\dot{P} = m_t - \alpha P_t$

$stock\ dynamics$

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3 A socio-economic model framework

- **NPV of a policy scenario with stock pollution effects**
- **T= removal period; emission stop**

$$max_T NPV = \int_0^T B(m)e^{-rt}\,dt - \int_0^T D(P)e^{-rt}dt - \int_T^{\infty} D(P)e^{-rt}dt$$

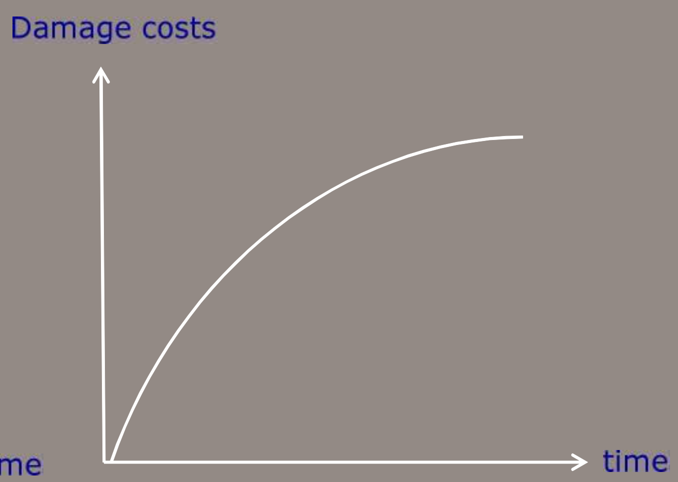
Discounted social benefits, *r* being the social discount rate. Benefits continue until T

Discounted damage costs until T, *r* being the social discount rate.

Discounted damage costs from T to infinity, *r* being the social discount rate.

- **An SEA must demonstrate at what T discounted benefits of a PBT/vPvB outweigh overall discounted damage costs!**

3 A socio-economic model framework



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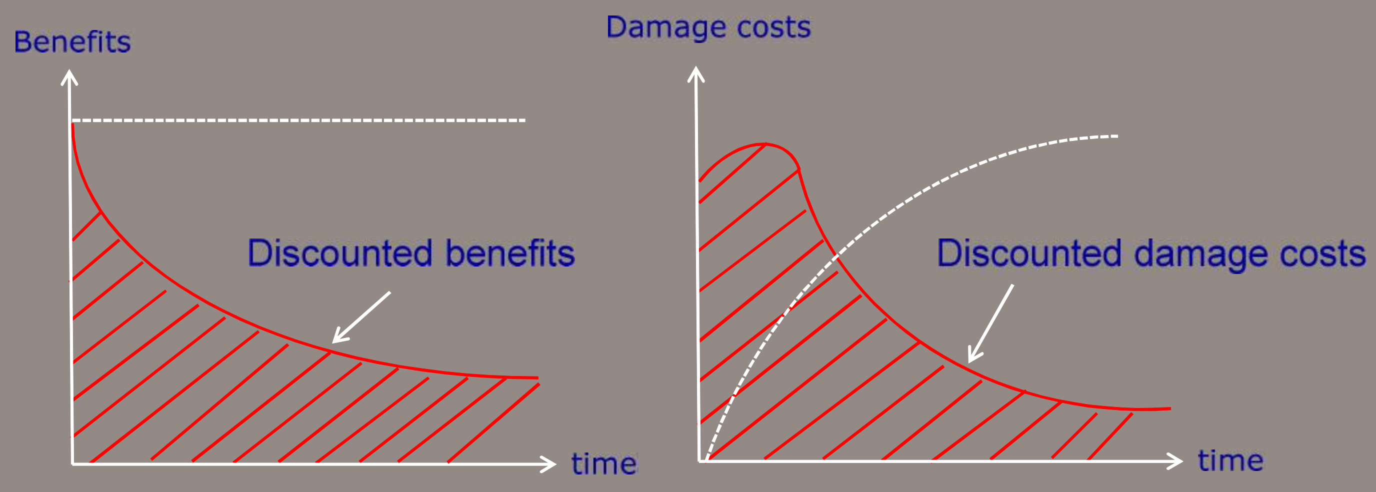
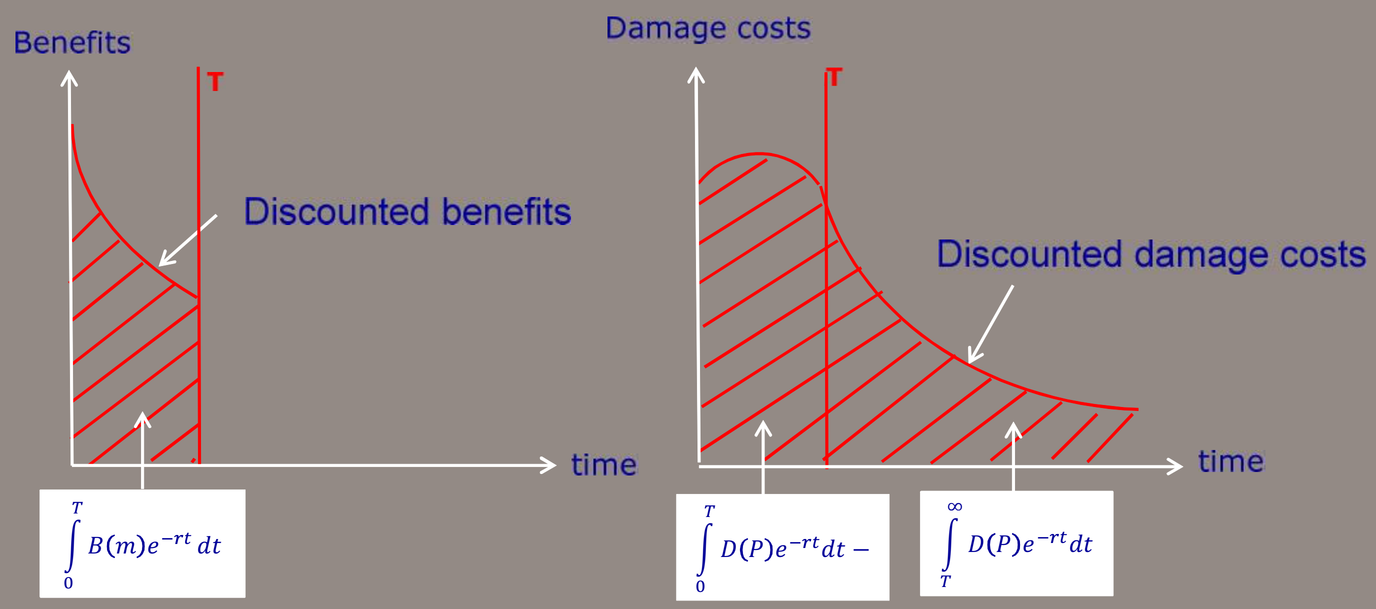
3 A socio-economic model framework



- **For toxic and persistent chemicals authorisation should be granted until marginal benefits exceed marginal damage costs.**

3 A socio-economic model framework



- **For toxic and persistent chemicals authorisation should be granted until marginal benefits exceed marginal damage costs.**

3 A socio-economic model framework

Chemical *i*

→ a) Toxic
- Damage costs at *t* depend on emissions at *t*
- With constant emissions authorisation is a “now or never” decision.

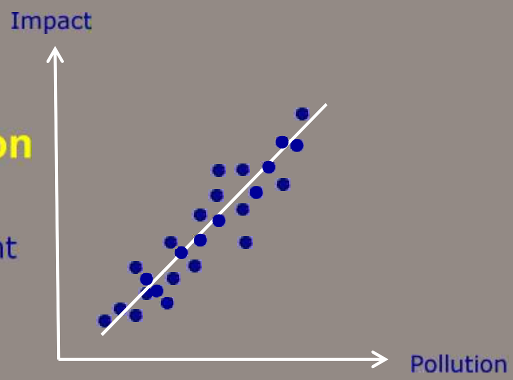
→ b) Toxic and persistent
- Damage costs at *t* depend on the stream of emissions from previous periods and the decay of the chemical
- Authorisation is an optimal timing problem

➢ **The optimal time T for removing a PBT or vPvB chemical depends on...**

3 A socio-economic model framework

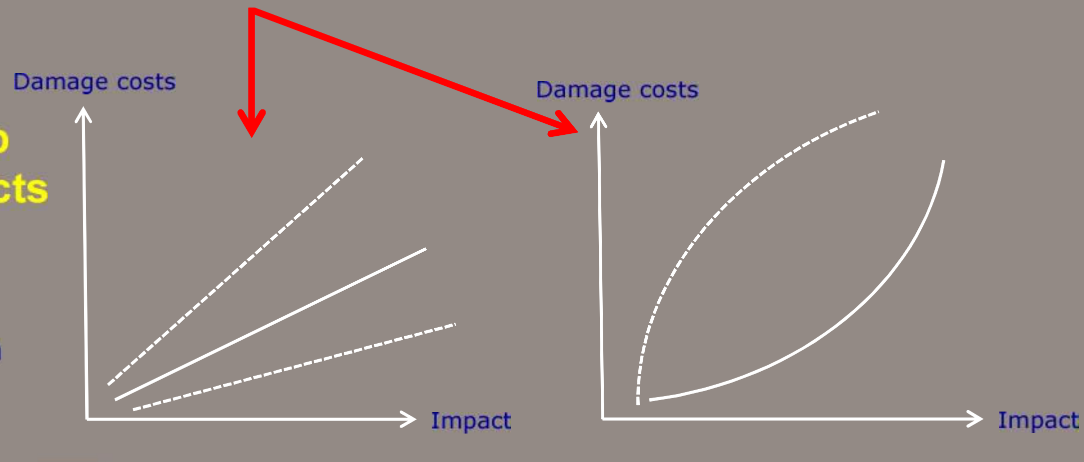
1. Relationship between pollution and impacts

→ Impact assessment



2. Relationship between impacts and damage costs

→ Impact valuation study



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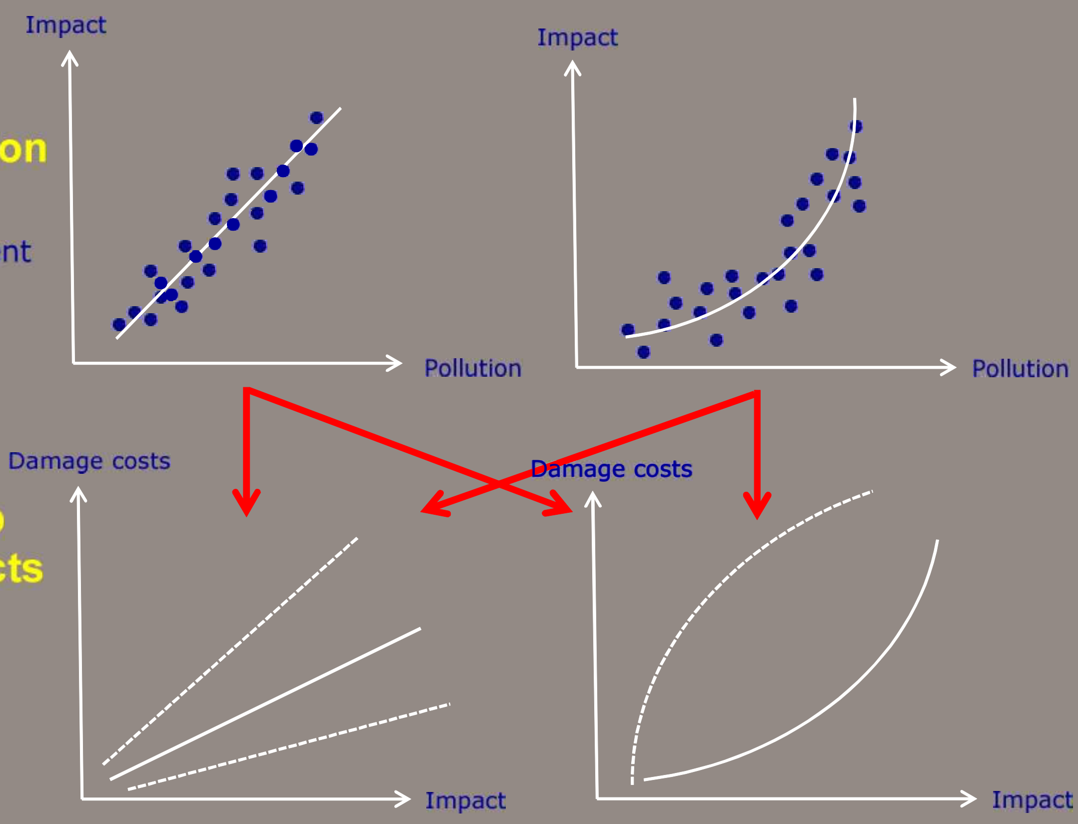
3 A socio-economic model framework

1. Relationship between pollution and impacts

→ Impact assessment

2. Relationship between impacts and damage costs

→ Impact valuation study



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3 A socio-economic model framework

Chemical *i*

- a) Toxic
  - Authorisation is a "now or never" decision
- b) Toxic and persistent
  - Authorisation is an "optimal timing problem"
    - 1) linear damage function
      - Constant marginal damage costs
    - 2) non-linear damage function
      - Increasing or decreasing marginal damage costs

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3 A socio-economic model framework

- **How can the optimal period T for granting/refusing an authorisation be determined?**

$$maxNPV_t = \int_0^T B(m)e^{-rt}\,dt - \int_0^T D(P)e^{-rt}dt - \int_T^\infty D(P)e^{-rt}dt$$

- The maximisation problem can be solved analytically in order to determine T:
  → integrate out
  → differentiate with respect to T
  → solve the first-order condition for T

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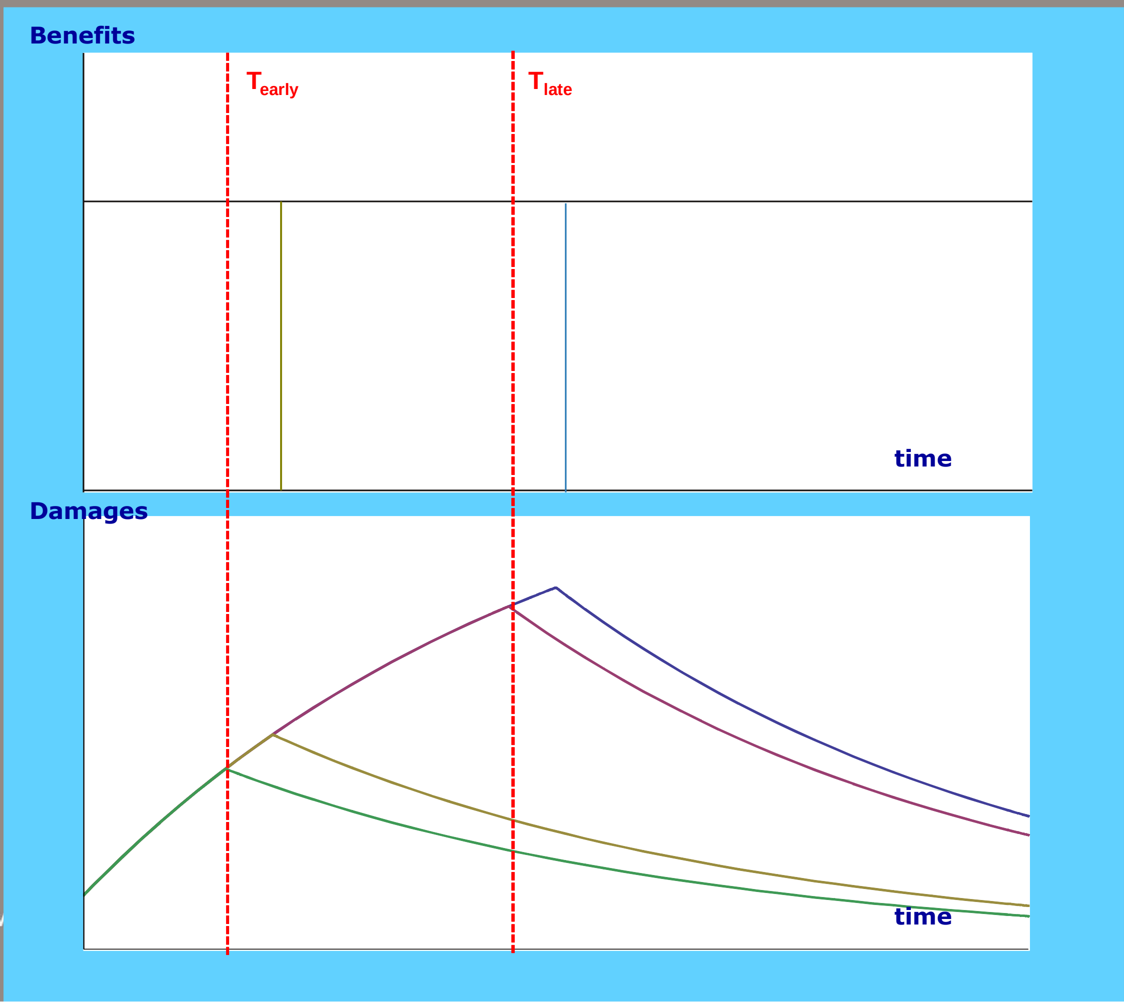
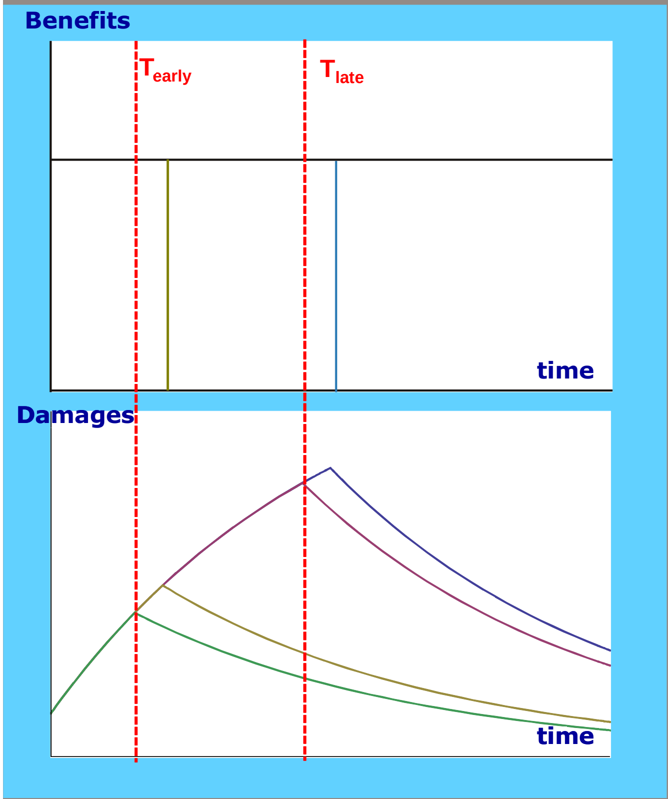
- Illustration: Simulation of optimal T for **a linear damage function**



4 First results and implications for decision-making

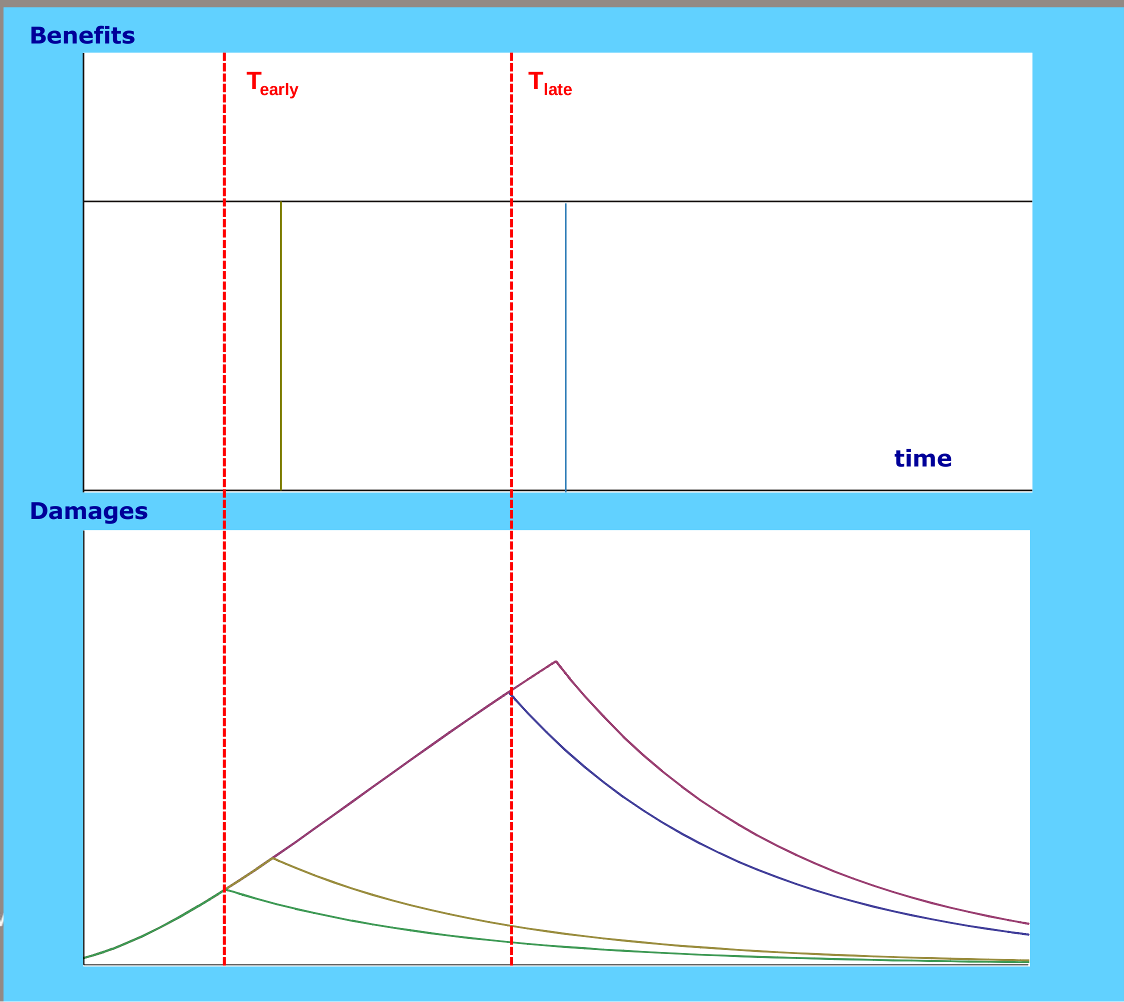
- Illustration: Simulation of optimal T for **a linear damage function**



- The difference between marginal damage costs and marginal benefits is independent of the stock for all T!

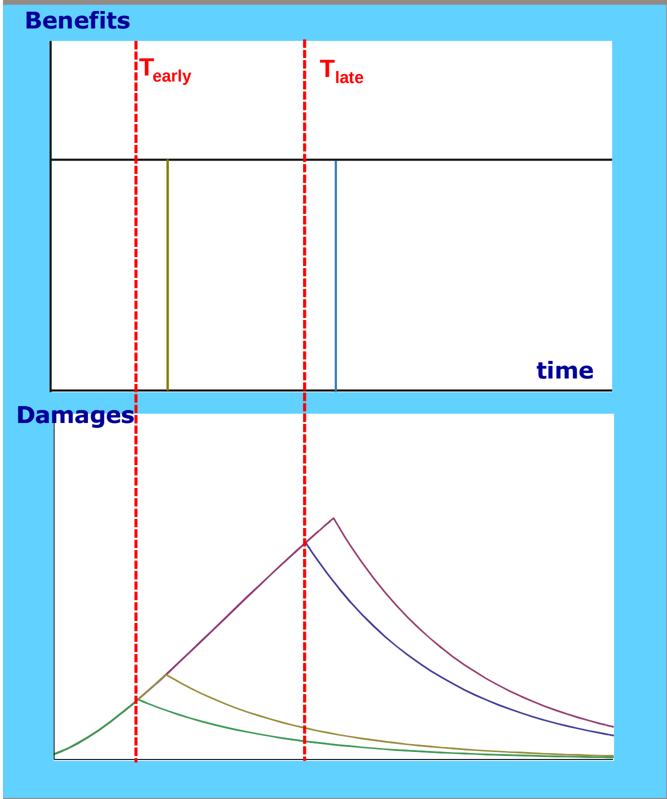
↔ Remove the substance now or never, depending on the values for α, r, marginal benefits and marginal damage costs

- Illustration: Simulation of optimal T for **a quadratic damage function**



4 First results and implications for decision-making

- Illustration: Simulation of optimal T for **a linear damage function**



- Constant marginal benefits have to be balanced against increasing marginal damages
- Solving the optimal timing problem gives an interior solution for an optimal T
- The optimal T depends on the initial stock P_0, the decay α, the discount rate, and on marginal benefits and costs.

4 First results and implications for decision-making

- Illustration: Simulation of optimal T for **a quadratic damage function**

α	0.1	0.05	0.01
P_0	0.1	0.05	0.01
0	7.96	4.33	1.56
1	6.9	3.3	0.56
2	5.7	2.22	immediate ban
5	1.03	immediate ban	immediate ban

- For a given discount rate and constant emissions, the optimal T is the earlier
  → the higher the initial stock
  → the more persistent the chemical

4 First results and implications for decision-making

Chemical *i*

- a) Toxic
  - Authorisation is a "now or never" decision.
- b) Toxic and persistent
  - Authorisation is an optimal timing problem
    - 1) linear damage function
      - Authorisation is a "now or never" decision.
    - 2) non-linear damage function
      - Increasing or decreasing marginal damage costs
        - 2.1) decision on authorisation is irrevocable
          - Determine optimal T from solving the optimal timing problem
        - 2.2) decision on authorisation is revisable
          - Switching solutions possible

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5 Proposed research agenda

- **Conclusions**
  - Persistent chemicals are stock pollutants, i.e. the pollution stock at a certain period depends on emissions in previous periods
  - The socio-economic modelling framework can be applied for determining optimal decision solutions on authorisation for any emission scenario and damage function
  - The decision rule for toxic, persistent chemicals is not *if* an authorisation should be granted, but until what period the chemicals should remain in use
  - The optimal time for removal of a PBT depends on the shape of the damage function
  - For non-linear damage functions optimal time for removal depends on the decay, the discount rate, marginal benefits and damage costs, and the revocability of authorisation decisions

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5 Proposed research agenda

Chemical *i*

- a) Toxic
  - Authorisation is a “now or never” decision.
- b) Toxic and persistent
  - Authorisation is an optimal timing problem

1

Emission scenarios

Emission pathways

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5 Proposed research agenda

Chemical *i*

- a) Toxic
  - Authorisation is a “now or never” decision.
- b) Toxic and persistent
  - Authorisation is an optimal timing problem
    - 1) linear damage function
    - 2) non-linear damage function

1

Emission scenarios

Emission pathways

2

Shape of damage and benefit function

Parameter values α, r

Valuation studies

CEA

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5 Proposed research agenda

Chemical *i*

→ a) Toxic

- Authorisation is a "now or never" decision.

→ b) Toxic and persistent

- Authorisation is an optimal timing problem

→ 1) linear damage function

→ 2) non-linear damage function

→ 2.1) decision on authorisation is irrevocable

- Determine optimal T from solving the optimal timing problem

→ 2.2) decision on authorisation is revisable

- Switching solutions possible

1
Emission scenarios
Emission pathways

2
Shape of damage and benefit function
Parameter values α, r
Valuation studies
CEA

3
Simulation of different implementation scenarios; case studies

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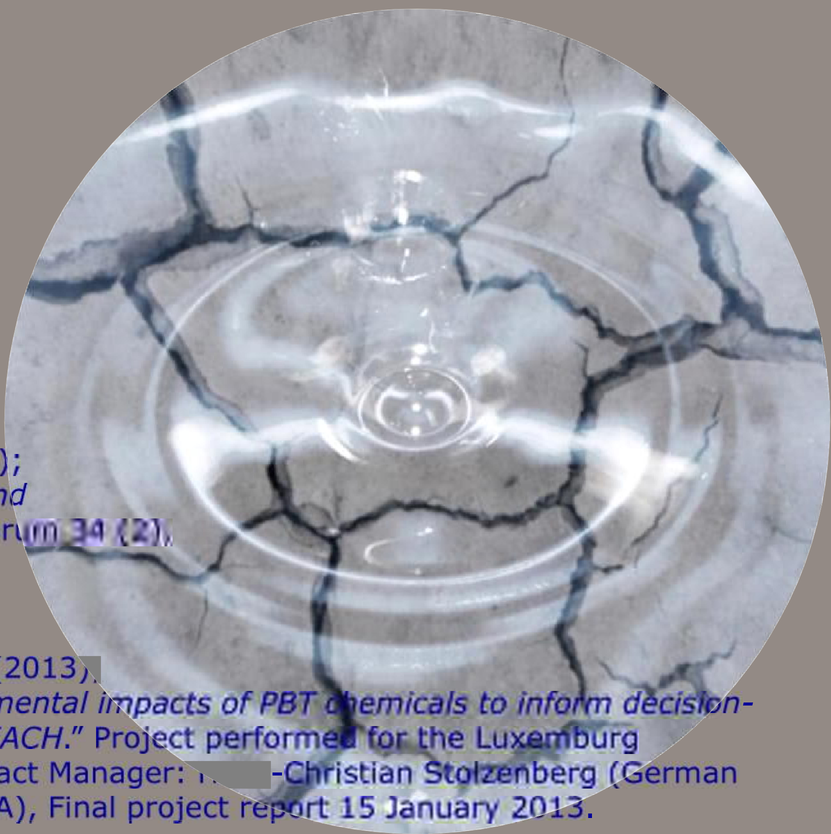
Thank you for your attention!



➢ Further reading:

- Gabbert, S., Weikard, H.-P. (2010); „*A Theory of Chemicals Testing and Regulation*." Natural Resources Forum 34 (2), 155-164.

- Gabbert, S, Scheringer, M, Ng, C (2013) "*A framework for valuing environmental impacts of PBT chemicals to inform decision-making on authorisation under REACH*." Project performed for the Luxemburg Environment Agency, Client Contract Manager: [illegible]-Christian Stolzenberg (German Federal Environment Agency | UBA), Final project report 15 January 2013.

- Gabbert, S. (2013); „*Decision-making on the authorisation of toxic, persistent chemicals: A stock-pollution approach." In progress.*

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Economic valuation of environmental impacts in SEA under REACH: Possibilities and limitations

Study commissioned by RIVM, Dutch National Institute for Public Health and the Environment

Sarah Bogaert – Nele Deleebeeck (Arcadis Belgium)
Julia Verhoeven – Martijn Beekman – Dick Sijm (RIVM)

RSC Workshop, 6 Sept 2013

Socioeconomic Valuation of Hazardous Chemicals Control

Imagine the result

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Objectives of the study

- To which degree are the available economic valuation methods applicable for evaluation of environmental impacts in a SEA REACH context?
- Can a conceptual framework be derived?
- Test the applicability of selected methods with potential – both for restriction and authorisation
- Make recommendations for future research

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Occasion: RIVM study

- Quantitative prototype methodology for EIA of use of chemical substances in BAU versus Policy Scenarios
- 3 case studies: HBCDD, NP & Zn in gutter systems
- How to take impact quantification further to economic valuation?

3

… and other recent work

- RPA, 2011. Assessing the health and environmental impacts in the context of socio-economic analysis under REACH. Part 2. The proposed logic framework and supporting case studies
- ECETOC, 2011. Environmental impact assessment for socio-economic analysis of chemicals: principles and practice. Technical report No. 113
- WCA, 2011. Refinement or environmental risk assessment outputs for use in socioeconomic impact assessment under REACH

4

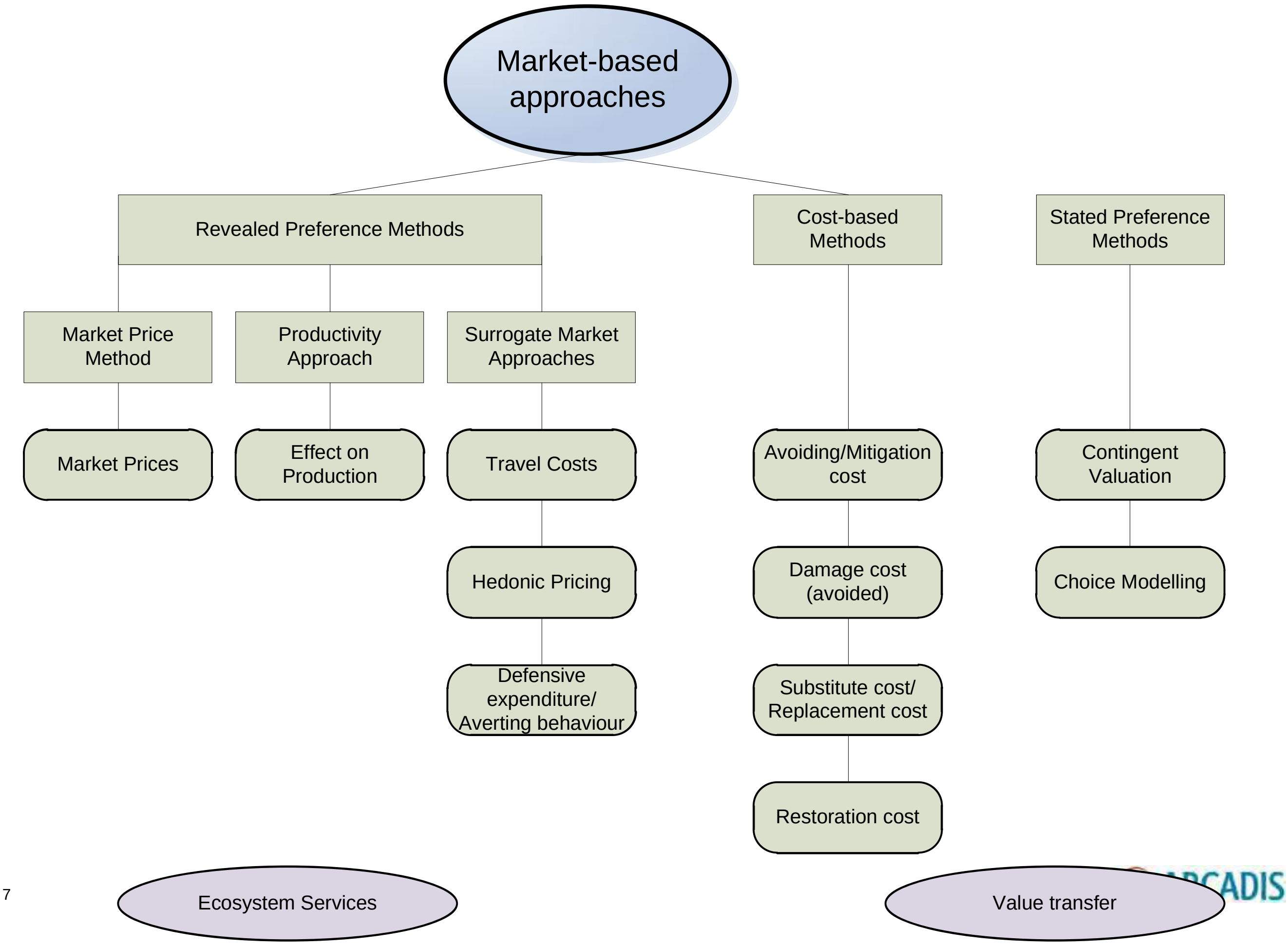
From risk assessment to quantitative EIA

Risk assessment	Impact assessment
❖ What is done in a CSR ❖ Often a lot of assumptions ❖ (Reasonable) worst case	❖ What is done in SEA ❖ Assumptions are avoided as much as possible ❖ Should be more realistic
Outcomes	**Outcomes**
❖ Risk characterisation ratio (RCR) ❖ Potential risk for a certain effect to occur ❖ Existence of a risk ❖ Strength in evidence of the risk ❖ Indication of the risk ❖ Control measures	❖ A PBT ranking score (not necessarily representing absolute differences) ❖ A normalised impact in terms of equivalents of a reference chemical ❖ An estimated reduction in population density and/or biomass for one or several target species or groups of target organisms ❖ A fraction of potentially disappeared or potentially affected species ❖ A change in ecological status as defined in EU Directives (e.g., WFD) ❖ Volume of media affected ❖ Exposure-based proxies (physical indicators), such as tonnages, emissions, number of sites, monitoring data, etc. ❖ A (quantitative) description of the contribution of the chemical substance to the status of a certain ecosystem service ❖ Etc.

Context of EIA endpoints

- Indirect effects usually not covered by REACH hazard info
- Potential of ecosystem functionality as an endpoint – lack of knowledge on:
  - (ir)replaceability of species
  - Species' relative contribution to ecosystem functioning
  - Potential of ESS concept
- Geographic scale and duration of impacts should influence hazard & exposure assessment, but also economic valuation
- Considerable sources of uncertainty

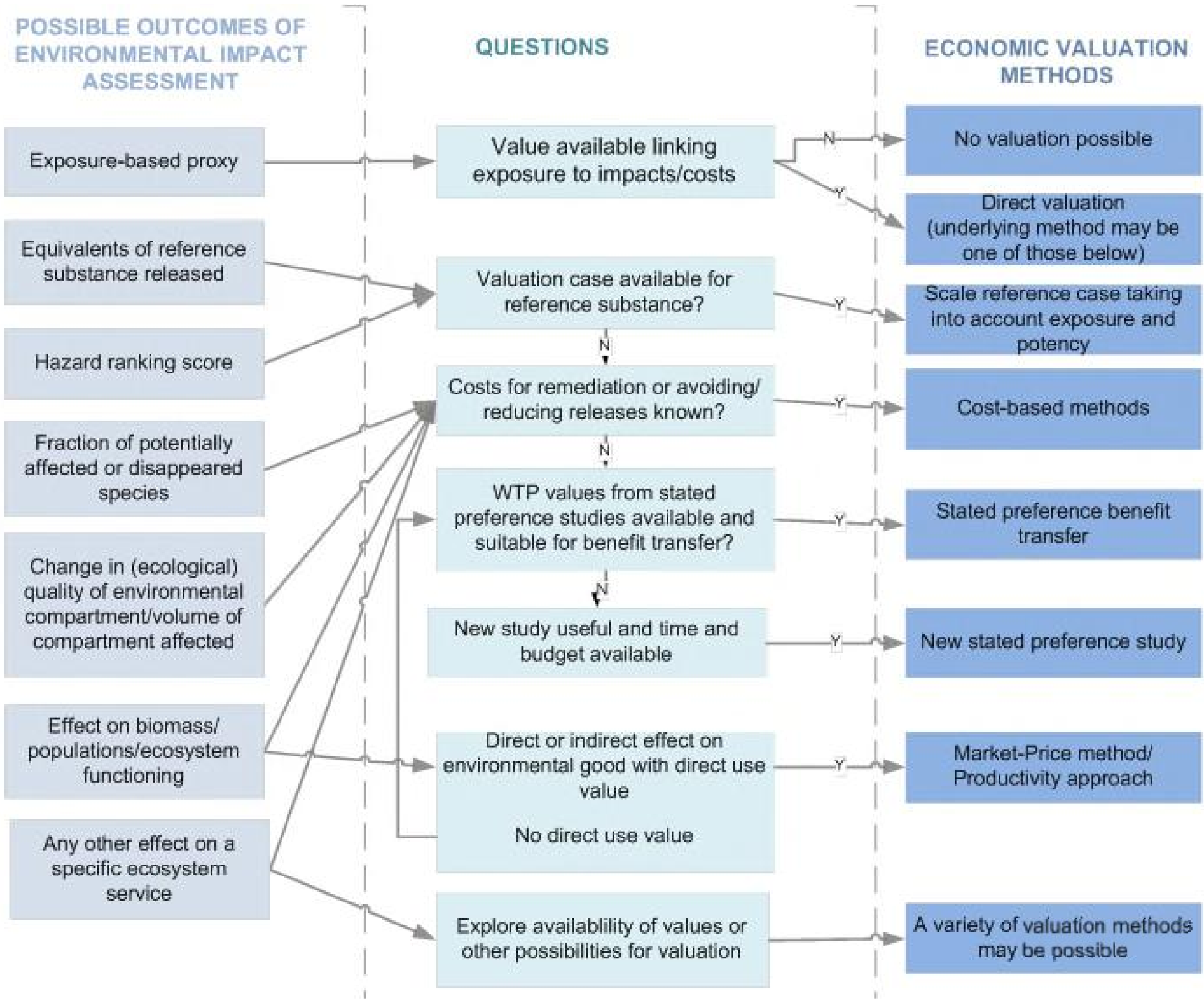
Economic valuation methods



Potential of economic valuation methods depending on environmental impact outcome

	Market Price/ Productivity Approach	Hedonic Pricing Method	Travel Cost Method	Defensive Expenditure Method	Cost based Methods	Stated Preference Methods
Hazard ranking score						
Normalised impacts in terms of a reference chemical/Exposure-based proxies						
Reduction in population density and/or biomass for (a group of) target species / A fraction of potentially disappeared of affected species						
Change in ecological status of (a part of) an environmental compartment / Volume of media affected / Contribution to status of ecosystem services						

Decision tree



Illustrative cases

1. Avoidance cost method
2. Stated preference methods and link % disappeared or affected species and water quality
3. Scaling of reference cases
4. Ecosystem services approach

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Avoidance Cost Method

- Can CEA/implementation cost of ERMs be used as a proxy for the economic value of environmental impacts?
- Potential for use in an SEA under Restriction and Authorisation, BUT under certain conditions
- ERMs in CSR = Baseline -> only **additional** ERMs for valuing **remaining** environmental impacts
- Selection of measures preferably done by means of objective standard (e.g. PNEC)
- ERMs should be technically feasible and not have significantly lower cost-effectiveness: risk of over-estimation of impacts!
- Beware of circular reasoning
- Difficult to assess share of unit cost attributable to individual substance
- Implementation degree requires assumptions influencing WTP for measures

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Avoidance Cost Method

Recommendations for further research:

- Real case testing to evaluate efforts needed and interpretation issues
- EU wide study of factors influencing implementation of ERM would need to be substance specific
- Potential may be questionable

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Combining SPM with PAF/PDF (water quality)

- PAF/PDF has limited compatibility with valuation methods except SPM – however potential difficulties in interpretation of PDF/PAF concept
- WTP studies available regarding WFD WQ status/classes however difficulties to transfer values (e.g. Brouwer et al., 2007)
- WQ Ladders (e.g. Hime et al., 2009) linking ecological status to measurable chemical limits
- Some difficulties:
  - WQ Status not only determined by biological aspects
  - Non-continuous character of WQ class system -> only a drastic reduction of use/emissions of a single chemical may result in a change of WQ class?

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Combining SPM with PAF/PDF (water quality)

Recommendations for further research:

- How to consistently link the # of species observed to biological WQ classes, e.g. via existing biotic indices or new scoring system
- How to make use of existing WQ ladders for chemicals EIA – need to establish relations between indicator values/ parameters attributing water bodies to water quality classes
- Development of a continuous WQ scale?
- Potential of a new EU-wide CVM/CR study

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Scaling of reference values/cases

Illustrative case showed potential of scaling of reference valuation cases:

- for groups of similar PBT substances (no linear relationships between hazard score and impact), or
- for groups of substances with similar hazards for which specific hazard scores are used to indicate difference in potency between chemicals

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Scaling of reference values/cases

Illustrative case showed potential of developing transferable indicators to simplify environmental impact valuation

- For ozone depletion, acidification, certain endocrine disruption effects, etc. -> EUR/kg of a reference chemical emitted per year (reference costs of actions to lower emissions)
- For chemicals for which hazard scores exist that are related to a reference chemical (for which the hazard score is typically 1)
- Are such indicators already available in other research fields such as ESS/LC(I)A?

Further investigation is needed

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Ecosystem Services

- Potential of ESS concept: economic value of certain ESS affected by environmental release of REACH substances is rather well-established and would allow straightforward valuation
- But insight needed on specific impact of individual chemicals on certain ESS, distinguished from 'combined' impacts of pollutants or combination of pollutants and other influencing factors
- Key question for future risk assessment: should absolute biodiversity be preserved or should focus be on ecosystem functionality?

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Value transfer

- Lack of values for transfer to new studies – allowing to link impact of a single chemical
- Stated preference surveys for individual substances and representative for the whole of EU27 are very time and resource intensive
- Feasibility of deriving WTP (functions) for avoiding potential environmental impacts from chemicals, covering various EU27 contexts?
- Feasibility of correct transfer to isolated impact from single substance and share of EU population holding the WTP?

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Conclusions

A lot of potential is out there!

Unfortunately, no ready-for-use solution yet

3 most promising ones:

- Link with water quality
- ESS
- Rescaling

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Any questions?

Socio-Economic and Economic Valuation aspects:
S.Bogaert@Arcadisbelgium.be

ENV & HH risk and impact assessment:
N.Deleebeeck@Arcadisbelgium.be

Copy of the study? Please contact RIVM:
julia.verhoeven@rivm.nl

Thank you for your attention!

ARCADIS

VU University Amsterdam

Economic valuation of the uncertain benefits of micropollutants removal

Roy Brouwer
in collaboration with Ivana Logar, Eawag

IVM Institute for Environmental Studies

Outline presentation

- Policy context, main objectives
- Design case study
- Some main results
- Conclusions and recommendations

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2

Policy context

- Water quality improvement in Switzerland through removal of micropollutants (MPs) from water bodies
- MPs = chemical compounds from pharmaceuticals, personal care products, pesticides, and chemicals used in industry in the aquatic environment at very low concentrations (µg/l or ng/l)
- Effects MPs on environment and human health highly uncertain
- MPs might have potentially adverse impacts on aquatic ecosystems (Kidd et al., 2007) or affect drinking water sources, but harmful effects on humans not yet proven (Schwab et al., 2005; Bruce et al., 2010; Burkhardt-Holm, 2010)

Objectives

- **Generally**: what is the public sense of urgency and willingness to pay to remove micropollutants through upgrading wastewater treatment plants in Switzerland?
- **Specifically**:

- How do we represent uncertain effects?
- Role of risk communication (risk ladder)
- Preference uncertainty, choice consistency, hypothetical bias
- Temporal stability of stated preferences and WTP (test-retest, comparing CE and CV)

Risk communication

- Many stated preference studies value small risks and risk reductions (e.g. value of statistical life or natural hazards)
- Validity and reliability of results derived from these studies depend on how risk is conveyed to respondents in a survey
- Limited number of SP studies deal with risk communication and its impact on welfare estimates - all use CV method
- Handful of CV studies examine effect of different communication devices on welfare estimates (Loomis and duVair, 1993; Corso et al., 2001; Botzen and van den Bergh, 2012)
- Risk ladders proven to be an effective communication tool, but inflate WTP in CV (Dekker et al., 2011)
- No study (yet) that examines effects of risk communication using a repeated choice experiment

Hypothesis

- through repeated choices both respondent ambiguity and the possible procedural variance introduced by the risk ladder are expected to decrease or even disappear

Representation of environmental risks

- Developed in direct collaboration with eco-toxicologists at Eawag and VU-IVM over approx. 6 months time period
- Pretested:

- 2 rounds of face-to-face interviews (n=80)
- 1 online pretest (n=122)

Representation of environmental risks

- "The effects of some of these remaining chemicals on the environment and human health are not well understood, especially "hormone active substances" like estrogens, which originate from contraceptive pills. Scientific research has shown that the discharge of these substances into surface water can affect plants and animals in water. Fish can develop, for example, both male and female organs or male fish can become female. This can disrupt fish reproduction and reduce the number of fish and fish species. The effects on humans are still largely unknown and require more scientific research."

Representation of environmental risks

List of 15 micropollutants:

- Atenolol
- Azitromycin
- Bezafibrat
- Carbamazepin
- Diclofenac
- Ibuprofen
- Sulfamethoxazol
- Clarithromycin
- Metoprolol
- Naproxen
- Trimethoprim
- Benzotriazol
- Diazinon
- Mecoprop
- Methylbenzotriazol

Potential environmental risk levels:

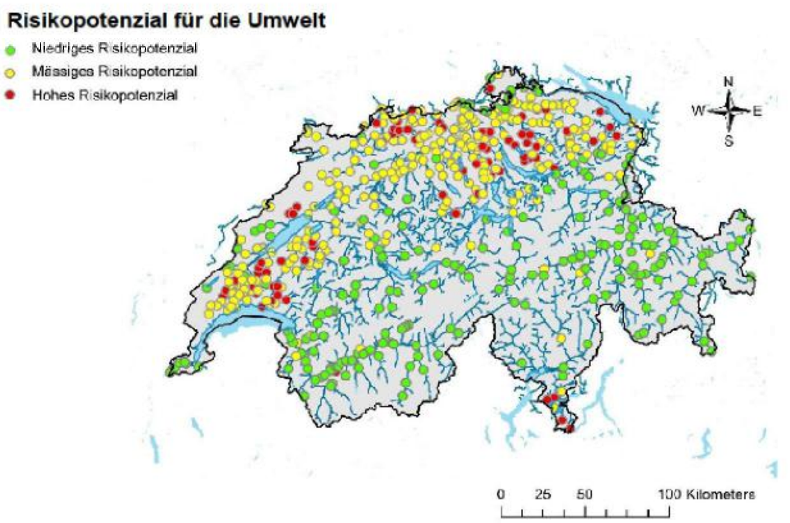
0 MPs exceeding EQS: **Low potential environmental risk**

1 - 3 MPs exceeding EQS: **Medium potential environmental risk**

4 - 6 MPs exceeding EQS: **High potential environmental risk**

downstream from 543 wastewater treatment plants in Switzerland

environmental concentration levels estimated with a substance exposure model (Ort et al., 2009)



Data: Eawag/BAFU (Ort et al. 2007 and 2009; Abegglen and Siegrist, 2012)
Basis: swisstopo (Art. 30 GeoIV): 5704 000 000/
Vector25©2008, DHM25©2008
Reproduced with the approval of swisstopo/JA100119

Wir möchten Sie bitten den folgenden Teil zu lesen:

Es existieren Pläne die **Abwasserreinigungsanlagen** in der Nähe von Schweizer Seen und Flüssen **zu verbessern** und zusätzliche **Forschungsprojekte, zu den Auswirkungen der verbleibenden Chemikalien auf die allgemeine Gesundheit**, zu finanzieren.

Das Entfernen dieser Chemikalien im Abwasser und weitere Investitionen in neue Forschungsprojekte sind **kostspielig**. Diese extra Kosten würden **zusätzlich auf die, von jedem Haushalt jährlich gezahlte, Wasserrechnung geschlagen** werden.

Ihnen wird jetzt eine Anzahl von Karten mit verschiedenen Optionen gezeigt, wie ein mögliches Risikopotenzial für die Umwelt reduziert und derzeitiges Wissen über die Auswirkungen auf den Menschen verbessert werden kann. Jede Karte wird zwei Möglichkeiten zeigen, wobei Sie sich für eine entscheiden sollen.

Jede Möglichkeit beschreibt:

- Die Verringerung des Risikopotenzials für die Umwelt von einem derzeit hohen (rot) Risikopotenzial zu einem mässigen (gelb) oder niedrigen (grün) Risikopotenzial für Wasserpflanzen und -tiere.
- Den Umfang für die Verringerung des Risikopotenzials: für Ihren Kanton oder die ganze Schweiz.
- Die Verfügbarkeit von neuen wissenschaftlichen Erkenntnissen über die Auswirkungen der Chemikalien auf den Menschen in den nächsten 5, 10, 15 oder 20 Jahren.
- Die extra Kosten, die zusätzlich pro Haushalt auf Ihre jährliche Wasserrechnung geschlagen werden.

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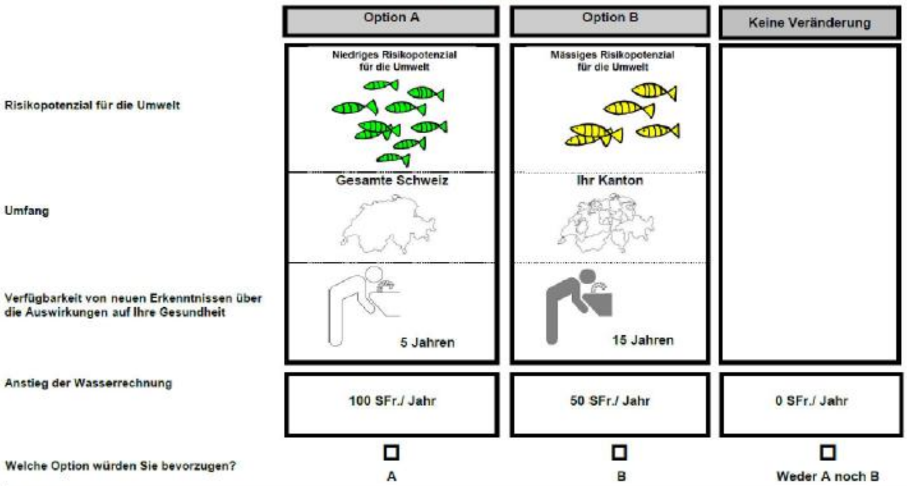
11

BEISPIELKARTE



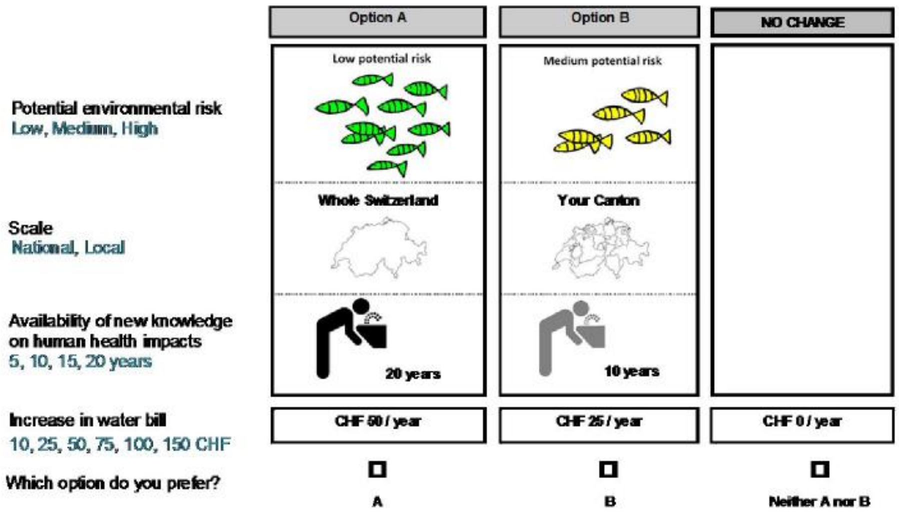
Erklärung

Option A bedeutet eine Verringerung des potenziellen Umweltrisikos von der derzeitigen Situation zu einem niedrigen Risiko im ganzen Land. Außerdem werden wissenschaftliche Erkenntnisse, als Basis für angemessene Massnahmen zum Schutze der allgemeinen Gesundheit, in den nächsten 5 Jahren zur Verfügung stehen. Ihre Wasserrechnung wird sich um 100 Franken erhöhen.

Option B bedeutet dass Ihre derzeitige Wasserrechnung jährlich auf 50 Franken ansteigen wird. Das potenzielle Umweltrisiko wird sich dabei nur in Ihrem Kanton von der derzeitigen Situation zu einem mäßigen Risikolevel verringern. Wissenschaftliche Erkenntnisse werden, als Basis für angemessene Massnahmen zum Schutze der allgemeinen Gesundheit, in den nächsten 15 Jahren zur Verfügung stehen.

Die **dritte Option** bedeutet, dass es keine Veränderung der derzeitigen Situation und keinen Anstieg Ihrer Wasserrechnung gibt.

Design choice experiment



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Followed by question about choice certainty on a scale 0-10

13

Risk ladder

The following overview shows different **risks of dying due to different causes**. Exposure to chemicals in drinking water is one of these risks. **If none of the chemicals** in surface water **are removed** before drinking, the chance of dying from drinking contaminated water is more or less **equal to** the **chance** of **dying from the flu** (one in every 100 thousand people). Hence the **chance of dying from very low concentrations of the remaining chemicals** like **estrogens in surface water** that is **also used for drinking water is** even **smaller** than this.

	Cause of death	Average risk (exposure level)
Higher Risk	Skin cancer from sun exposure	1 in 5 people run the risk of dying
	Active cigarette smoking (1 pack a day)	8 in 100 people run the risk of dying
	Motor vehicle accident	1 in 100 people run the risk of dying
	Crossing the street as a pedestrian	1 in 1.000 people run the risk of dying
	Outdoor air pollution	1 in 10.000 people run the risk of dying
Lower risk	Chemicals in drinking water	1 in 100.000 people run the risk of dying

Source: Snyder, S.A., Trenholm, R.A., Snyder, E.M. (2010). *Toxicological relevance of EDCs and pharmaceuticals in drinking water.* Report of the American Water Works Association Research Foundation.

Risk perception

Description	Categories	Subsample: With risk ladder	Subsample: Without risk ladder
Questions preceding the risk ladder			
Familiarity with the information about MPs and their potential effects	Never heard of it before (%)	1.6	2.0
	Somewhat familiar (%)	21.5	25.1
	Familiar (%)	48.2	49.0
	Very familiar (%)	28.7	23.9
Perception of the risks of MPs for the environment and human health	Not risky at all (%)	4.5	3.2
	Somewhat risky (%)	38.1	44.5
	Risky (%)	47.8	42.5
	Very risky (%)	9.7	9.7
Questions following the risk ladder			
Self-reported change of view about the risk of MPs on human health	Yes (%)	22.7	n/a
	No (%)	77.3	n/a
Awareness of the potential environmental risk in respondent's area of residence	Yes (%)	22.7	24.3
	No (%)	77.3	75.7

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Estimated choice model

	Subsample: With risk ladder	Subsample: Without risk ladder	Pooled model
Variable	**Coefficient**	**Coefficient**	**Coefficient**
Mean estimates of random parameters			
Low potential environmental risk	0.860***	0.707***	0.777***
National scale	0.355***	0.414***	0.391***
Availability of new knowledge on human health impacts	–0.042***	–0.060***	–0.053***
Non-random parameters			
Price	–0.008***	–0.006***	–0.007***
Dummy for subsample (1=with risk ladder)	—	—	–7.581***
Perceived risk of MPs (1=not risky at all; 4=very risky)	1.061***	0.385	—
Perceived risk of MPs × Dummy for subsample	—	—	1.170***
Respondent's average choice certainty	0.333**	0.381**	—
Respondent's choice certainty × Dummy for subsample	—	—	0.534***
Household income / 1000	0.202*	–0.012	0.066
Constant	–2.024	1.165	4.872***
Standard deviations of random parameters			
Low potential environmental risk	1.804***	1.294***	1.547***
National scale	1.410***	0.940***	1.192***
Availability of new knowledge on human health impacts	0.082***	0.053***	0.068***
Standard deviation of the error component (σ)	4.109***	2.581***	3.826***
Log likelihood	–1628.143	–1628.143	–3256.287
LR test (χ^2)	1031.479***	1053.608***	2064.245***
Pseudo R^2	0.317	0.324	0.317
Number of observations	14882	1482	2964

*, ** and *** denote $p<0.1$, $p<0.05$ and $p<0.01$

WTP estimates (CHF/household/year)

	Subsample	
	With risk ladder	Without risk ladder
Reduction of potential environmental risk from current to low level	104.52 CHF [16.38]	119.32 CHF [24.31]
Reduction of potential environmental risk at national instead of cantonal level	42.72 CHF [11.31]	70.13 CHF [15.33]
Having new knowledge about the impacts of MPs on human health available 1 year sooner	4.94 CHF [1.26]	10.05 CHF [1.67]

Summary effect risk ladder on

1) Choice behavior
- Swait-Louviere (1993) test indicates equality of preference parameters
- Self-reported risk perception and choice certainty affect choice behavior

2) WTP estimates
34% lower in subsample with risk ladder; differences not significant

3) Choice certainty
- Swait-Louviere test shows significantly lower error variance in subsample with risk ladder, which we interpret as higher choice certainty
- Self-reported choice certainty levels (0-10) not significantly different
- Assumption that risk ladder reduces choice uncertainty and procedural error variance through repeated choices cannot be confirmed

Conclusions and recommendations

- Results based on models and respondents' self-reported perceptions are contradictory
- Further research:
  - Are models or respondents more trustworthy?
  - Does a greater absolute risk level generate different results?
  - Does a relative position of the risk in the risk ladder matter?

VU University Amsterdam

Thank you for your attention

r.brouwer@vu.nl

IVM Institute for Environmental Studies

Economic benefits of controlling PBT substances: Two case studies

Stavros Georgiou (HSE), Susana Mourato (LSE)
Elise Schroeder (LSE), Bill Watts (EA) and
Jason Yun (LSE)

Background: PBT substances

PBT: Persistent, Bioaccumulative and Toxic

- Remain in the environment for a long time and can be transported over long distances
- Builds up in the environment through the food chain
- Potentially toxic to wildlife and have an impact on human health

PBTs are difficult or impossible to remove from the environment. Will they cause problems?

- Unknown: **Inconclusive evidence** on potential long-term adverse impacts, research on-going
- Require regulation under the **Precautionary Principle** : lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. Better safe than sorry…

Background: PBT Valuation Challenge

- Effects & risks poorly understood (ambiguity)
- Incomplete Damage Function Chain
- Upstream v downstream valuation in df chain?
- Upstream: How to define commodity to be valued & which actually affects utility?
- Need for general (albeit imprecise) info on DF linkages…but is this enough?
- Problems of scope insensitivity; scenario rejection; etc

Two case studies

CASE STUDY 1

Chemicals:

- PBT: Cyclotetrasiloxane (D4)
- vPvB: Cyclopentasiloxane (D5)

Uses:

- Improve the quality of personal care products: antiperspirants, shampoo, moisturizers, make-up, etc.

Environmental impact:

- Washes off and builds up in sediment and water bodies
- Potential to enter bird and mammal food chain

CASE STUDY 2

Chemicals:

- Deca-Bromodiphenyl Ether (Deca-BDE)

Uses:

- Effective flame retardant in textiles and plastics

Environmental impact:

- Enters the environment through dust particles or contaminated waste water
- Potential negative reproduction and developmental effects on wildlife
- Potential human health risks?

Valuing changes

When markets exist	• Market prices
When markets exist but are imperfect	• Adjusted market prices
When markets do not exist ('intangibles')	• Use non-market valuation techniques

Market goods

Non-market goods

Stated preference methods

- Based on the assumption that people's intended behaviour in hypothetical/ simulated markets (e.g. survey) reflect preferences for non-market assets
- Valuation based on intended future behaviour
- **Choice experiments**

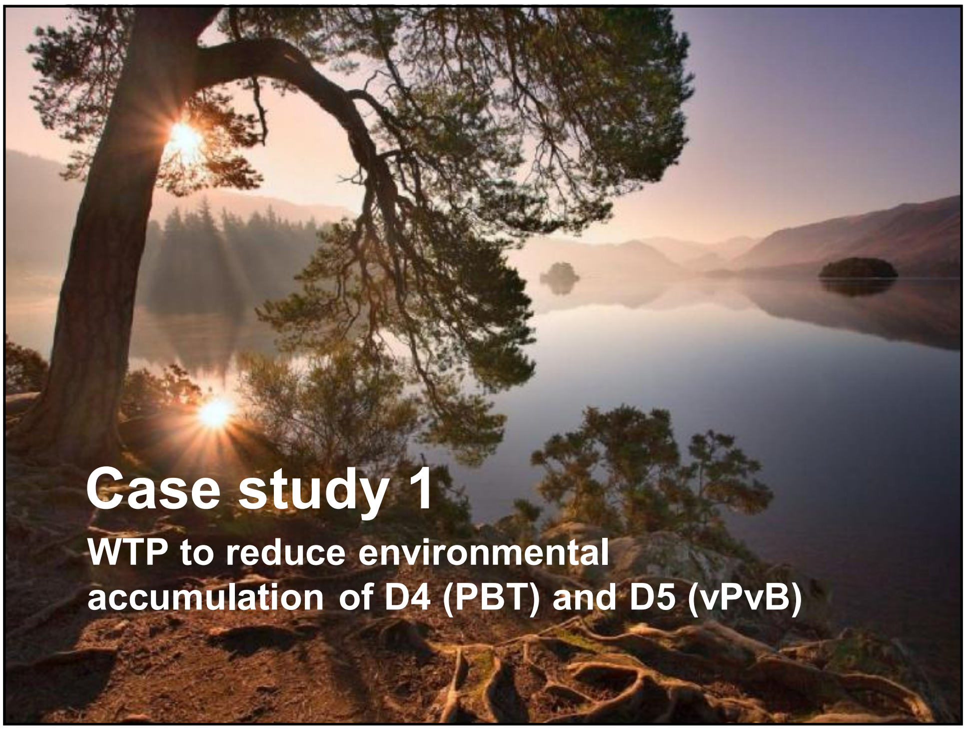
Choice experiments

Assumes that the value of a good is a function of its characteristics

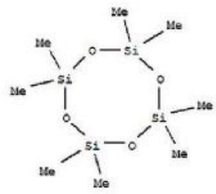
Individuals are asked to choose their preferred alternatives amongst various constructed scenarios

- Each scenario is a function of various attributes (including price)
- Each attribute varies at different levels
- Choices involve trade-offs
- WTP is inferred indirectly

Option:	1	2	Current Situation
Environmental Accumulation of Pentasiloxane	Low	Low	High
Personal Care Product Quality	Standard	Superior	Superior
Annual Household Bills Increase	£5	£30	£0



Objective



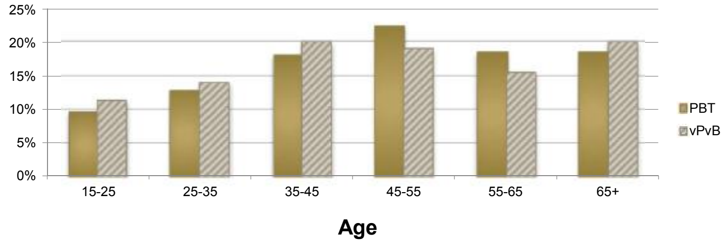
Estimate WTP for reduction in environmental accumulation of D4 and D5

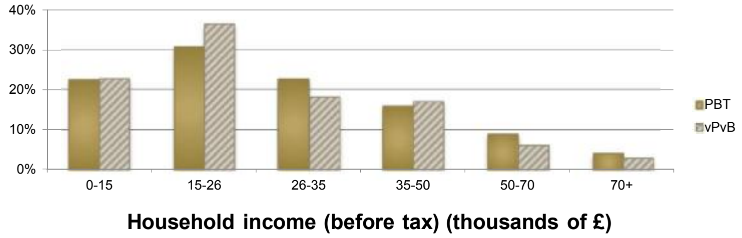
- Web-based choice experiments
- Sampling: on-line panel representative of UK population (sex, age, income, region)
- 2 split-samples:
  - D4 sub-sample: N=415
  - D5 subsample: N=414
- July and August 2013

Outline of the questionnaire

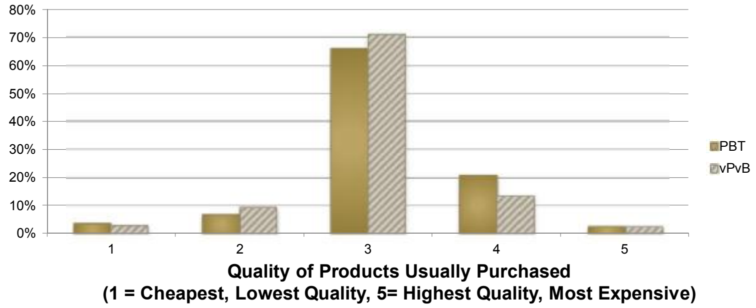
- **Behaviour**
  - Personal care products, environmental behaviour
- **Attitudes**
  - Environmental concern, personal care products
- **Scenario description**
  - Current Situation: High accumulation of substances in environment
  - Proposed situations:
    - Substances no longer released into environment, although current levels will persist
    - Personal care product substitutes will have less desirable properties
    - Substitution of chemicals is costly
- **Value elicitation**
  - Choice experiment cards
  - WTP inferred indirectly from preferred option
  - Annual increase in household bills
- **Follow-up questions**
  - To screen for protests and other misleading responses
  - Opinions of survey and reason for WTP
  - Ranking of attribute importance
- **Demographics**
  - Sex, age, income, education

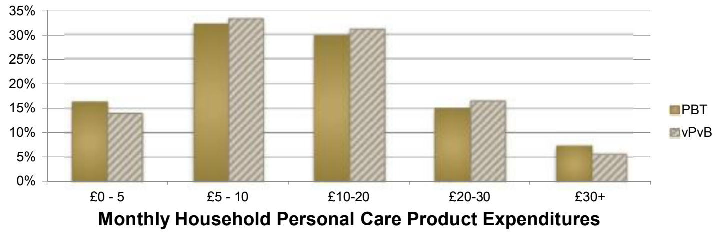
Demographics





Personal care products use





Environmental behaviour

	Female	Engages in Envtl. Friendly Behaviour	Member of an Envtl. Org.	Donation in past year to Envtl. Org
PBT survey	54%	92%	17%	27%
vPvB survey	57%	91%	19%	27%



Outline of the questionnaire

- **Behaviour**
  - Personal care products, environmental behaviour
- **Attitudes**
  - Environmental concern, personal care products
- **Scenario description**
  - Current Situation: High accumulation of substances in environment
  - Proposed situations:
    - Substances no longer released into environment, although current levels will persist
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  - Opinions of survey and reason for WTP
  - Ranking of attribute importance
- **Demographics**
  - Sex, age, income, education

Scenario

Respondents were shown detailed descriptions of product benefits:

- **Superior quality products:**
  - Apply smoothly, evenly
  - Dry quickly without feeling cold
  - Leave no residue or grease
  - Leave hair shiny and silky
  - Have a long shelf life
  - Safe for consumers
  - Have a silky dry feel
  - Low irritation
- **Standard quality products:**
  - Providing only some of the above

Respondents were shown detailed descriptions of environmental accumulation risks:

- **High accumulation:**
  - Substances are accumulating in the environment and aquatic food chain, may enter bird/mammal food chain, persistent
  - Toxic (D4) or not known to be toxic (D5)
- **Low accumulation:**
  - Substance no longer released into environment, but current levels persist for many years
- Effects largely unknown
- **Decrease in environmental accumulation is costly**

Attributes & levels

Attribute	Levels
Environmental accumulation	High$_{SQ}$, Low
Personal care product quality	Superior$_{SQ}$, Standard
Annual household bills increase	0$_{SQ}$, £1, £5, £10, £20, £40

Example choice card
(6 cards per respondent)

Please look at the options in the card below and choose the ONE option you prefer most on THIS card.

Option:	1	2	Current Situation
Environmental Accumulation of Tetrasiloxane	High	Low	High
Personal Care Product Quality	Superior	Superior	Superior
Annual Household Bills Increase	£1	£40	£0

Option 1 ○ Option 2 ○ Current Situation ○

Notes:
- Reminder description of attributes and levels shown alongside each card
- Reminders of budget constraints, other expenditures, be realistic
- Reminder that there are many other PBTs building up in the environment

Choice experiment model

Variables	Coefficient	
Reduced environmental accumulation	2.82	***
High product quality	0.78	***
Increase in bills	-0.10	***
Toxicity*Reduced env. accumulation	0.48	**
Donation* Reduced env. accumulation	1.33	***
Age*High product quality	-0.69	***
Constant for status quo	0.52	***

Notes:
- Both sub-samples combined (PBT and vPvB): N=829
- Toxicity interaction identifies the PBT sub-sample
- $*p \leq 0.10$; $**p \leq 0.05$; $***p \leq 0.01$

Marginal WTP results

Variables	WTP		95% Conf. Int.	
Reduced environmental accumulation	£29.28	***	£25.42	£33.15
High product quality	£8.30	***	£5.78	£10.82
Toxicity*Reduced env. accumulation	£4.99	**	£0.57	£9.40
Donation* Reduced env. accumulation	£13.86	***	£8.73	£19.00
Age*High product quality	-£7.15	***	-£10.35	-£3.95

Notes:
- WTP in higher household bills per year
- *p ≤ 0.10; **p ≤ 0.05; ***p ≤ 0.01

Discussion

Positive WTP for reduction in environmental accumulation

WTP is higher to reduce the toxic substance

WTP environmental benefits higher than WTP product quality

Is it enough for a ban?

Limitations

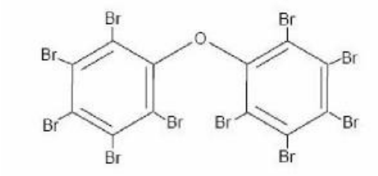
Difficult to monitor rational responses

- Speedsters (less 6 min) and incompletes excluded (N=3,000)
- Of the N=829 valid responses, 1/3 completed in less than 10 minutes
- Of all choices made, 17% were dominated
- Several people did not want to pay more due to non-use or not caring about product quality

Survey design (e.g. choice of attribute levels) may influence WTP outcomes

Focusing bias on D4 and D5

Objectives



Estimate WTP for reduction in environmental accumulation of Deca-BDE

- Web-based choice experiments
- Sampling: on-line panel representative of UK population (sex, age, income, region)
- 3 split-samples:
  - Environmental risks / Deca-BDE: N=414
  - Environmental and human risks / Deca-BDE: N=414
  - Environmental and human risks / All PBTs: N=414
- July and August 2013

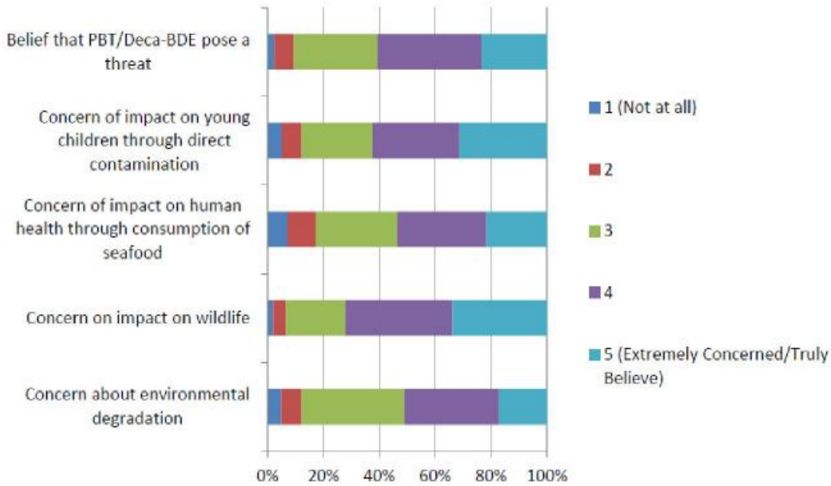
Outline of the questionnaire

- **Behaviour**
  - Current use of textiles and electronics at home, use of fire alarm/insurance, victim of fires
- **Attitudes**
  - Concern for environmental degradation, adverse impacts on wildlife and human health
- **Scenario description**
  - Current situation: High relative levels of risks of impacts without regulation
  - Proposed situations:
    - Relative levels of risk of impact on wildlife and human health may potentially be low if Deca-BDE is not used
    - Potential substitutes may not be as effective and hence may increase risk of death from household fires
    - Substitution of chemical is costly
- **Value elicitation**
  - Choice experiment cards
  - WTP inferred indirectly from preferred option
  - Annual increase household expenditure
- **Follow-up questions**
  - To screen for protests and other misleading responses
  - Opinions of survey and reason for WTP
  - Ranking of attribute importance
- **Demographics**
  - Sex, age, income, education

Demographics

Category	Statistics		
Gender		**Socio-Economic Band**	
Male	48.8%	ABC1	40.7%
Female	51.2%	C2DE	59.3%
Age		**Conservation Org. Member**	
15-24	8.7%	Yes	11.5%
25-34	16.9%	**Conservation Donor**	
25-44	18.4%	Yes	26.0%
45-54	18.7%	**Regions**	
55-64	16.2%	Northern Ireland	1.7%
65 and above	21.0%	Wales	5.5%
Education		Scotland	8.2%
Primary	3.9%	North East	4.2%
GCSE/O'Levels/GCE	27.2%	North West	11.9%
A'levels/HNC/HND/BTEC	24.4%	Yorkshire and Humber	8.3%
College/Uni. Degree	29.4%	East Midlands	7.4%
Higher Degree	8.3%	West Midlands	8.7%
Professional Qualifications	6.8%	East	7.8%
Pre-tax Household Income		London	13.2%
<£15,000	26.5%	South East	13.8%
£15,000-£25,999	33.3%	South West	9.3%
£26,000-£34,999	20.1%		
£35,000-£49,999	12.4%		
£50,000-£70,000	4.7%		
>£70,000	3.0%		

Attitudes



Outline of the questionnaire

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  - Current use of textiles and electronics at home, use of fire alarm/insurance, victim of fires
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  - Opinions of survey and reason for WTP
  - Ranking of attribute importance
- **Demographics**
  - Sex, age, income, education

Survey A information: Environmental risks/Deca-BDE

- Uses of Deca-BDE as a fire retardant:

Electric and Electronics Equipment
- Housing and internal components of TV, printer, audio equipment , batteries , computers etc
- Electrical wiring and cables of ships, airplanes etc

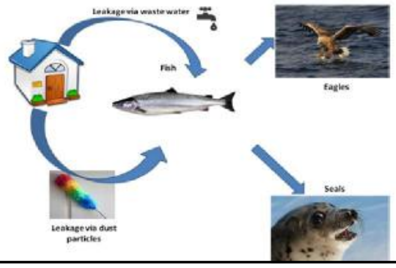
Textiles and Furniture
- Upholstery textiles e.g. sofa, office chairs
- Textiles e.g. curtains and table cloths

Building and Construction
- Pipes
- Ventilation Air Ducts
- Stadium Seats

Survey A information: Environmental risks/Deca-BDE

- Impact of Deca-BDE on the environment:

Persistence	• Does not break down easily and remains in the natural environment for a very long time • May have the ability to be transported over long distances, reaching remote regions like the Arctic
Bio-Accumulative	• Accumulates in the environment through the food chain • May reach high levels in species such as otters, birds of prey and Polar Bears
Toxic	• Reduces an animal's ability to grow, reproduce and/or behave in a normal way • May potentially affect human health as well



Survey A information: Environmental risks/Deca-BDE

- Impact of Deca-BDE on wildlife :

Scientists have found that impacts on reproduction and development can lead to declines in populations of animals such as the eagle and seal. Although there are very few cases of population declines caused by DECA exposure alone, continued low level contamination can still affect individual animals

Survey B information: Environmental and human health risks/Deca-BDE

- Potential human health risks from Deca-BDE, both directly and indirectly:

PBT substances may accmuluate in the body through the consumption of food such as fish

Direct exposure to PBT substances in consumer products and household dust

Transfer of PBT substances from mothers to their babies in the womb or during breast feeding

Survey C information: Environmental and human health risks/All PBTs

- Description of uses of some PBT substances, including Deca-BDE, D4 and D5:

Fire Protection
- The substances of interest to our study are added to materials such as textiles and plastics used in household products such as household appliances and furniture, electrical wiring, cables and pipes
- The addition of these substances reduces the chance of materials catching fire, so as to comply with strict Fire Safety Regulations in the UK
- Such regulations are estimated to save 180 lives per year in the UK from reduced risk of household fires

Personal Care Products
- The substances are also found in shampoos, anti-perspirants and many hair care products
- They are added to give a silky and non-greasy feel to the hair and skin, and/or to allow products to dry quickly

Marine equipment
- The substances are also used to coat marine equipment such as the hulls of boats and/or underwater pipes to prevent the build up of marine organisms like barnacles on their surface
- They thus help to reduce drag of the boat in the water and therefore reduce fuel consumption

Other Uses
- Pesticides to improve crop yields
- Lubricants for machinery in factories
- As an additive in the manufacture of dyes for textiles

Valuation scenario: Environmental risk change

Relatively Low Risk

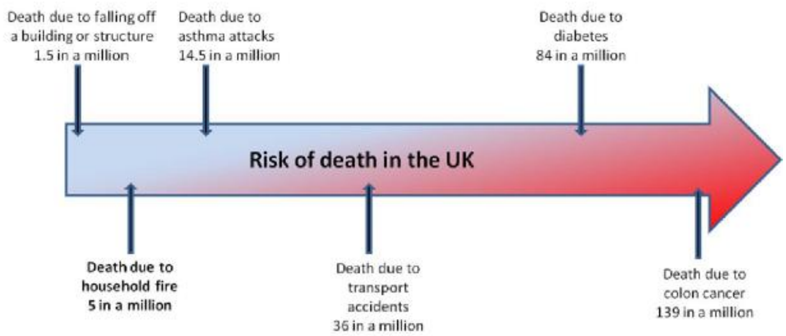
- Accumulation (build up) below levels considered dangerous with relatively **low** risk of impacting wildlife
- Accumulation (build up) below levels considered dangerous with relatively **low** risk of impacting human health

Relatively High Risk

- Accumulation (build up) above levels considered dangerous with relatively **high** risk of impacting wildlife
- Accumulation (build up) above levels considered dangerous with relatively **high** risk of impacting human health

Valuation scenario: Death from fire risk change

Risks of death from household fire described using a visual aid to compare between the different risks of death in the UK



Attributes & levels

Attribute	Levels
Risks of death from household fire	5 in a million$_{SQ}$, 10 in a million, 15 in a million
Relative level of risks of impact on wildlife	High$_{SQ}$, Low
Relative level of risks of impact on human health*	High$_{SQ}$, Low
Annual increase in household expenditure**	0$_{SQ}$, 5, 25, 50, 75, 100 pounds

*Only for Surveys B and C

**Only the status quo option contains £0 increase in annual household expenditure

Survey A: Example choice card (8 cards per respondent)

Please consider the options given in the card below. The reminder in the graphics below are for your convenience.

	Current Situation	Alternative 1	Alternative 2
Risks of death due to household fires	5 in a million	15 in a million	5 in a million
Relative level of risks of impact on wildlife	High	Low	High
Increase in annual household expenditure	£ 0	£ 25	£ 75

Which of the options above would you choose?

Current Situation ○ Alternative 1 ○ Alternative 2 ○

- Reminder description of attributes and levels shown alongside each card
- Reminders of budget constraints, other expenditures, be realistic
- Reminder that there are many other PBTs building up in the environment

Surveys B &C: Example choice card

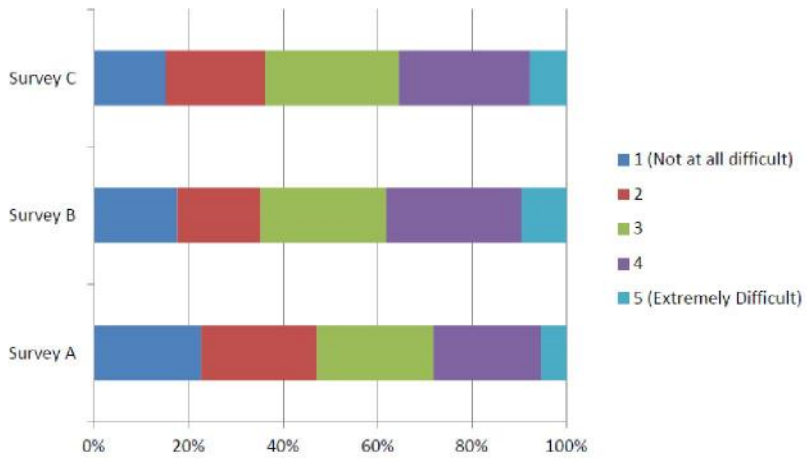
Please consider the options given in the card below. The graphics below are there as reminders for your convenience.

	Current Situation	Alternative 1	Alternative 2
Risks of death due to household fires	5 in a million	15 in a million	10 in a million
Relative level of risks of impact on wildlife	High	High	Low
Relative level of risks of impact on human health	High	Low	High
Increase in annual household expenditure	£ 0	£ 50	£ 5

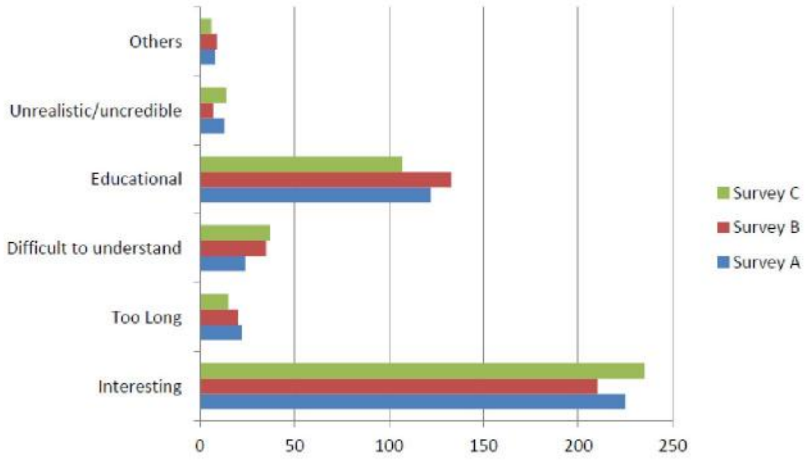
Which of the options above would you choose?

Current Situation ○ Alternative 1 ○ Alternative 2 ○

Difficulty in answering choice questions



Survey Opinions



Survey A: Choice experiment model

Variables	Coefficient	
Fire death risk	-3.14	***
Reduced wildlife risks	2.95	***
Increase in expenditure	-0.03	***
Wildlife concern*Reduced wildlife risks	3.11	***
Member or donor* ASC	-0.40	*
ASC (Constant for status quo)	1.60	***

Notes:
- *p ≤ 0.10; **p ≤ 0.05; ***p ≤ 0.01

Survey A: Marginal WTP results

Variables	WTP	
Fire death risk reduction (median value)	£1.40	**
Reduced wildlife risks	£95.94	***
Wildlife concern*Reduced wildlife risks	£101.35	**
Member or donor* ASC	-£12.99	***
ASC (Constant for status quo)	£52.09	***

Notes:
- WTP in higher household expenditure per year
- Implied VSL=£1.4million (from median WTP)
- *p ≤ 0.10; **p ≤ 0.05; ***p ≤ 0.01

Marginal WTP results across surveys

Variables	WTP A	WTP B	WTP B
Fire death risk reduction (median value)	£1.40**	£1.18**	£1.43***
Reduced wildlife risks	£95.94***	£38.08***	£26.76***
Reduced human health risks	--	£78.55***	£58.54***
Wildlife concern*Reduced wildlife risks	£101.35**	£52.84**	£51.55**
Member or donor* ASC	-£12.99*	--	--
ASC (Constant for status quo)	£52.09***	£32.00***	£15.14*

Notes:
- WTP in higher household expenditure per year
- Implied VSL=£1.2-1.4 million (from median WTP)
- *p ≤ 0.10; **p ≤ 0.05; ***p ≤ 0.01

Economic surplus of switching to alternatives

	Survey A	Survey B	Survey C
Economic Surplus (95% C.I.)	£145.20 (£109.96-£180.42)	£137.49 (£111.06, £163.92)	£129.14 (£98.45, £159.82)

Scenario:

- Alternative to Deca-BDE/PBT substances are harmless to the environment and/or human health and resulting risks are **low**
- Alternatives still meet fire safety regulations, i.e. **no increase in risks of death** from household fire
- Average respondents' socio-economic variables: annual household pre-tax income of <£26,000, aged below 65 and indicated high concern for risks of impact on wildlife population

Why are respondents willing to pay to switch to alternatives?

	Survey A (n=314)	Survey B (n=332)	Survey C (n=363)
Concerned about risks to wildlife	237	192	225
Concerned about risks to human health	-	245	269
Willing to pay due to uncertainty	171	145	185
Risks of death from household fire too small	106	111	117

Discussion

Large and meaningful WTP estimates for all attributes throughout the 3 surveys

- British public seems genuinely interested and concerned about the use of Deca-BDE/PBTs

Introduction of human health risk attribute decreases WTP estimates for wildlife risks

WTP for attributes does not increase when all PBT substances are valued compared to just Deca-BDE

Economic surplus are within a small (statistically insignificant) range of £129 and £145 per year, indicating a 'fixed' WTP for precaution as a whole across 3 surveys

Validity tests

	Survey A	Survey B	Survey C
Protestors	50 (12.0%)	35 (8.4%)	24 (5.7%)
Non-traders	3 (0.7%)	6 (1.4%)	15 (3.6%)
Failed consistency Tests	63 (15.2%)	78 (18.8%)	81 (19.6%)
Failed non-satiation tests	102 (24.6%)	70 (16.9%)	81 (19.6%)


Thank you!

Socioeconomic Valuation of Hazardous Chemicals Control: Issues, Challenges and Questions for Discussion

Royal Society of Chemistry, London
6 September 2013

Meg Postle

RPA
Risk & Policy Analysts

Where are We?

- Need to balance the uncertain benefits from taking a precautionary approach to the regulation of PBTs and vPvBs against the economic costs to society from the loss of a chemical
- Such balancing requires an understanding of the environmental hazards posed by PBTs, of the associated risks and, ideally, how these translate to effects
- It may also require consideration of synergistic and mixture effects
- In either case, scientific data on effects then needs to undergo some form of valuation for use in decision making

RPA
Risk & Policy Analysts

Environmental Risk Assessment

Starting point has to be consideration of the outputs of the risk assessment:

- Hazard assessment considers:
  - Toxicity effects for multiple environments (media): aquatic, terrestrial, higher predators, etc.
  - Toxicity across multiple organisms: microbial, invertebrates, vertebrates, etc.
  - Toxicity for different endpoints: survival, growth, reproduction, abnormalities, etc.
  - Other effects: persistence, bioaccumulation, endocrine disruption

RPA

EU Risk Assessment Process

- Ecotoxicity
  - Use critical (relevant) endpoints for most sensitive species & no-observed-effect-concentration (NOEC)
  - NOEC and 'assessment factors' used to derive a predicted-no-effect-concentration (PNEC)
- Exposure
  - Use (modelled) levels (including adjustment factors for uncertainty) for various media/scenarios to derive scenario-specific predicted environmental concentration (PEC)
- Risk characterisation ratio => RCR = PEC/PNEC
- RCR does not inform on: other effects in species on which PNEC based, effects in other species, type or extent of damage

RPA

Using RA Outputs – Key Issues

- Output of RA will be a Risk Characterisation Ratio for the most sensitive species → but SEA needs data underlying these and should also consider effects on other species and/or ecosystems
- Uncertainties surrounding use of PNECs: use of different endpoints, varying sensitivities for different species, acute versus chronic effects, assessment factors, etc.
- How to account for long-term and on-going nature of effects associated with PBT and vPvB properties
- Consideration of 'realistic estimates' not just 'worst case'?

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Using RA Outputs – Key Issues

- Does not require estimation of extent of exposures at elevated concentrations or of stock at risk
- Absence of monitoring data on environmental concentrations
- Ecosystems involve extremely complex interactions between multiple species
- May be unforeseen food-web consequences from impact on single species or trophic level

Of course, one can always go beyond the standard approach!

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Possible approaches and their Challenges – A Practitioner's View

- RCRs and qualitative descriptions of effects with quantification of emissions into the future and data on exposures
  - Provides no basis for comparing significance against the benefits of the continued use of the substance / costs of its loss
- Risk ranking/scoring methods, based on chemical properties
  - What ranking method? What endpoints?
  - How to interpret ranks/scores when comparing to benefits of continued use?
  - How to make trade-offs between a PBT and a carcinogen or reprotoxin?
  - Does one need to weight importance of different impacts if used as part of a CEA, for example?

Possible approaches and their Challenges – A Practitioner's View

- Assessment based on linkages to Ecosystem Services
  - Do these need to be redefined to be relevant to PBT properties?
  - What RA outputs are needed and how can they be translated to provide such an assessment?
  - Is this a necessary first step to valuation in this policy context?
  - Is it helpful? Provides no basis for directly comparing significance against the benefits of the continued use of the substance / costs of its loss
  - How to make trade-offs between a PBT and a carcinogen or reprotoxin?

Possible approaches and their Challenges – A Practitioner's View

- Use of Species Sensitivity Distributions as a proxy for 'damages'
  - Requires work beyond traditional RCR outputs to create underlying statistics. Are there sufficient data?
  - Assumes sensitivity in one species is predictive of other not tested species
  - Unable to define which species may be actually impacted within an ecosystem
  - Cannot infer consequences for the ecosystem's sustainability (e.g. don't know if keystone species are ones that would be impacted)
  - Potential for acting as basis for CEA or CBA?

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Possible approaches and their Challenges – A Practitioner's View

- Use of some form of Cost-effectiveness Analysis
  - Traditionally cost relates to € and effect to environment – is there a role for other models?
  - How should one measure effectiveness: proxy damage cost index based on risk ranking, fraction affected species, change in environmental burden?
  - Should the need to incorporate time become explicit, given accumulation aspect?
  - Can standard decision rules be used (CE ratio, Incremental CE ratio)?
  - Does it provide sufficient information on its own?

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Possible approaches and their Challenges – A Practitioner's View

- CBA provides the direct comparison of costs and benefits need for decision making under Authorisation, on disproportionate costs, etc.
- But, it requires good / reliable data on environmental effects, their significance and extent? Will we have such data?
- Is the standard framework appropriate or should a stock pollution model be promoted?
- Are the traditional valuation approaches applicable?
  - If so, should new studies be commissioned?
- Is benefits transfer valid? What constraints should be placed on its use, if any?
- Do we need a new paradigm in valuation to address the types of risk issues posed by PBTs and vPvBs?

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Questions for the Workshop

1. Do people value precaution? And if so, how can we best reflect or capture this value?
2. What is the real data gap between what risk assessors can provide and what economists need? Is it information on 'stocks' and exposure, cause and effect, fate and transfer mechanisms? Can these gaps be filled or will they always be there, and if they will always be there what are the implications for SEAs?
3. The presentation on a stock pollution approach suggests that the scientific case for control on precautionary grounds may vary across different types of SVHCs. Should such an approach be promoted? What are the implications for vPvBs?

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Questions for the Workshop

4. Methodological frameworks such as that proposed by RIVM promote a tiered approach, using different techniques for quantifying effects. Is further work required on the development of such techniques with a specific focus for their use in SEAs? If so, which ones should act as the focus? SSDs? Risk Ranking?
5. Can a systematic means of describing or classifying the (potential) effects associated with different environmental risks be developed? Does this need to go beyond a single species affected to the ecosystem level? Could an ecosystems services type framework be developed more specifically with such chemicals in mind in order to link the scientific case to human welfare endpoints? Is this a necessity to underpin monetary valuation?

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Questions for the Workshop

6. Can the scientific case based on precaution be expressed in a manner that the public can understand so that reliable valuations of the risks and uncertainties associated with PBTs and vPvBs can be derived? Or should other means for assessing the acceptability of the trade-offs arising from the control, or not, of these chemicals be developed?
7. What are the implications of the issues presented above for assessing the environmental benefits of controls on PBTs in the short term? Are the proposed approaches fit for purpose? What do we need in the longer term?
8. Can and should chemicals be analysed singly or as a chemical group with similar effect? E.g. as a group for WFD and Restrictions?

RPA Risk & Policy Analysts

Risk & Policy Analysts Limited
Farthing Green House, 1 Beccles Road
Loddon, Norfolk, NR14 6LT, United Kingdom

Tel: +44 1508 528465
Fax: +44 1508 520758
E-mail: post@rpaltd.co.uk
Website: www.rpaltd.co.uk

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