NORDIC WORKING PAPERS

Valuation Literature on Chemicals

A Description of an Inventory of Valuation Literature
on Chemicals

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DENMARK, THE NORWEGIAN ENVIRONMENT AGENCY AND THE FINNISH SAFETY AND
CHEMICALS AGENCY

INVENTORY OF VALUATION LITERATURE ON CHEMICALS

FINAL REPORT

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Preface

The purpose of this project has been to create an easily accessible inventory of studies that cover the full impact pathway from chemical exposure (or emission) to socio-economic valuation of the related health impacts. The main outcome of the project is an excel-based database of the 45 identified studies.

The majority of the project work – including development of search strategy, literature search, database design, and report draft – has been carried out by COWI A/S. The project leader at COWI was Michael Munk Sørensen. This work has been financed by the Nordic Council of Ministers (through the Nordic Chemical Group and the Environment and Economy Group).

The project steering group initiated the project and guided the consultants through general instructions and comments on report and database drafts, as well as finalisation of the report. The steering groups work has been financed by their respective governmental organisations. Travelling expenses and other meeting costs have been financed by the Nordic Council of Ministers.

Valuable comments have been received from Mikael Skou Andersen (Aarhus University) and Michael Holland (EMRC).

Future work

The steering group's ambition is that the outcomes of this project will be used by socio-economic analysts to aid assessments of chemicals policy. In order to keep the inventory as relevant and up to date as possible, we recommend that the inventory is revised within two years.

/The project steering group,

Mattias Carlsson Feng and Jenny von Bahr (Swedish Chemicals Agency), Thea Marcelia Sletten (Norwegian Environment Agency), Signe Krarup (Ministry of Environment and Food of Denmark), and Johanna Kiiski (Finnish Safety and Chemicals Agency)

Summary

This report presents the findings of a literature review of socioeconomic data relating to the benefits of chemical policies and regulation. The purpose of the project has been to create an easily accessible inventory of economic valuations that can assist socio-economic assessments. The review has identified about 45 articles and reports containing monetary valuations of chemical policies. The identified articles and reports are included in an Excel database, where the key information about each article/report is presented. The project was carried out by COWI A/S on behalf of and in close dialogue with The Swedish Chemicals Agency, The Ministry of Environment and Food of Denmark, The Norwegian Environment Agency and The Finnish Safety and Chemicals Agency in the period March to November 2016.

The aim of the literature review has been to identify studies most relevant for value transfer when carrying out chemical policy assessment. Therefore, focus in the search has been based on the following inclusion criteria:

- > studies that have considered the full impact pathway of a chemical (from emission or exposure to monetary valuation of health impacts and effects)
- > studies that focus on valuation of the health impacts
- > studies that focus on developed countries as opposed to developing countries.
- > more recent studies (studies published after 2005)

The database also includes a list of studies that were identified as relevant but not complying with all the above criteria. These studies are listed, but with less information about their content and their relevance for value transfer.

The search strategy has included:

- > A search of selected databases, including databases containing peer-reviewed literature, open literature and "grey"¹ literature, was conducted with the purpose of locating published research on health effects caused by exposure due to intended use of chemicals and the related cost of this exposure.
- > Relevant studies conducted within the REACH restriction and authorization processes were obtained. Only those studies providing monetary estimates are included.

¹ Term used to describe reports, working papers, studies etc. published outside of traditional academic and commercial publishing. It means that for example government policy document belongs to this category, as does this present report.

- > The searches have been conducted using relevant combinations of search terms (chemical and valuation/external costs/benefit/damage)
- > It should be noted that studies focusing on health impacts caused by air pollution (e.g. exposure to NO_x, SO_x, and particles) were not included in the scope of study².

The identified studies can support policy assessment by providing input and support to value transfer. The database includes information to identify the most relevant study or studies for specific applications. It is possible to sort by group of substance or by type of health impacts included in the studies. Based on an assessment of each study, a brief guidance note has been included in the database. It describes how each study might be used for value transfer. In most cases, the user will have to consult and read the study/report itself for details.

The key findings of the literature review are the following:

- > The main type of substances covered by the identified monetary valuations are heavy metals, e.g. lead or mercury. They are substances with well-documented health effects and have been subject to several assessments.
- > The second largest number of monetary valuations relate to substances with endocrine disrupting properties.
- > Pesticides is the type of substances that have been subject to the third largest number of monetary valuations.
- > Identified gaps include the following type of substances which are not specifically covered:
 - > Flame retardants
 - > Antimicrobials
 - > Plasticisers
 - > Respiratory allergens

Many of the studies have presented results in the format of unit damage costs. However, it is often difficult to extract all of the specific assumptions used in the valuation. Therefore, the user will need to review prospective articles or reports carefully to extract the unit values that could be applied in a value transfer situation.

² This delineation is based on the traditions of environmental policymaking where these air pollutants are managed by air quality units and not by the chemical policy units in most administration.

1 Introduction

Development of policies and regulations of chemicals often requires a balancing of costs and benefits. The benefits of chemicals regulations comprise reduced human health and environmental damages. The purpose of this project is to create an easily accessible inventory of economic valuations, which can assist socio-economic analysts in chemical agencies and elsewhere, in making accurate assessments based on best available knowledge. The study has focused on the valuation of human health effects; hence, studies that value the environmental effects are not included.

Large external costs³

Exposure to chemicals may lead to a number of health effects that have economic value in the form of cost of healthcare treatment, lost productivity of workers and personal welfare loss (e.g. pain and suffering from enduring an illness). These health effects can be of substantial economic value. As an example, the health benefits of the REACH regulation have been projected to be €50 billion over the first 30 years of its existence⁴.

Impact pathway approach

National and European chemical policies aims to regulate the use of chemicals and reduce the external cost from use of chemicals. Valuations of the health impacts from exposure to chemicals are central components in assessing the consequences of regulation and developing efficient policies.

The general approach, the impact pathway approach, is based on tracing the link from emissions to concentrations, to exposure, to health impacts (estimated based on dose-response relationships) and finally valuation of these impacts. The impact pathway approach is illustrated in Figure 2-1. The literature review focus on studies that include the full impact pathway. Having covered the full pathway, such studies are in principle better suited for supporting value transfer. It is easier to adjust the results of a study and use them in a new context when all elements of the pathway are included. If for example the level of emissions are different, it might be possible recalculate the values to reflect the situation and conditions where the value transfer is to be applied. Similarly, if the exposure is different or if the valuation of the impacts is different, the study results could be recalculated and reused in the new policy context.

Figure 2-1 also illustrates that policy interventions typically will aim at regulating emissions and thereby the level of exposure. For health effects, it means the direct exposures as well as exposures through environmental media. Changing the emissions is usually achieved through reducing the quantities of the unwanted chemicals used in the production process or in the products themselves. In other cases, the emission reduction is achieved through design of the products limiting any release of substances. The exposures can be more directly affected by requiring changes to the way the products are handled,

³ An external effect occurs when producing or consuming a good or service causes an (uncompensated) impact on third parties not directly related to the transaction. The adverse health effects that occur due to chemical exposure are examples of negative external effects (external costs).

⁴ http://ec.europa.eu/environment/chemicals/reach/background/i_a_en.htm

used, and disposed of by the consumers. Exposure in the work environment can also be affected by requiring certain protection measures to be applied.

Figure 2-1 Impact pathway and policy interventions

Relevance to users

Often, the assessment of policy impacts leaves no room for new, primary studies, due to the resource limitations. The second best alternative is then to utilise literature knowledge via economic value transfer. The socio-economic analyst needs a qualified overview of existing valuation studies. Then, the analyst can reuse and adapt the best available knowledge in the current policy context. Therefore, an inventory of relevant literature can be a helpful tool supporting value transfer. It can assist the socio-economic analyst by providing a solid starting point for doing new policy assessments where value transfer could be relevant. Having a comprehensive inventory would help to focus the data collection and reduce the need for doing a new literature study at the beginning of every new policy assessment. Furthermore, it can facilitate a more consistent approach and selection of studies used across different assessments.

A current challenge in chemicals policy is that on one hand, the number of studies is large and of varying applicability via value transfer. On the other hand, many substances, effects, pathways, affected populations etc. remain unstudied, and it may be difficult to establish a correlation between the chemical exposures and the specific health impacts.

A recent expert workshop on "Valuing the Health Impacts of Chemicals" organised by the European Chemicals Agency (ECHA) in Helsinki (January 2016) pointed to focal points for future work within valuation of chemicals:

- > Cost of illness and morbidity related to chemicals in EU Member States
- > Valuation of neurological impacts

Figure 2-2: Current knowledge challenges

Project aim

The objective is thus to create a literature overview at a low level of detail, but with a broad application span and an inventory structure that allows the user to narrow down literature sources to the most relevant ones in terms of substance, geography and impact type. Based on this, the socio-economic analyst can choose which sources to study in detail and apply in value transfers.

In addition, the project gives an indication of the current state of knowledge. Which substances and impacts have been subject to comprehensive socio-economic valuation? Where are the apparent knowledge gaps? These reflections could serve to guide future work within valuation of chemicals.

Contents

This report provides a short overview of the findings as a supplement to the Microsoft Excel based spreadsheet that forms the inventory itself. The contents of the report are:

- Methods: Literature search and review, and inventory structure
- Findings and discussion
- Appendices including extracts from the inventory and literature list

2 Method

This section describes the method we have used for the literature search process. It also describes the content of the resulting database.

2.1 Study focus and scope

The focus of the study is to develop a comprehensive database with valuation studies relevant for chemical policy assessments. The scope can be defined as follows:

- > Focus on studies with valuation of health effects (excluding environmental effects)
- > Present key information on the studies that can facilitate value transfer

It has not been within the scope of this work to assess the scientific quality of the identified studies. The database supports access to the study or report itself, while the user will need to assess whether it is suited for value transfer in the given situation and then to extract the relevant health impact values for the value transfer.

In the initial pilot searches, studies involving environmental effects were included. These pilot searches revealed a limited number of studies focused on the environmental effects where a full impact pathway had been assessed and monetarily valued. Therefore, it was decided not to specifically search for environmental impacts. The database includes in the gross list of identified studies also a few studies that cover environmental impacts.⁵

The fact that focus has been on the health effects means that in order to make a complete assessment of a particular substance, the user would have to complement the information included in this inventory with data on the environmental effects.

2.2 Study approach

The study approach can be described by the search strategy applied and by the subsequent screening process of the gross list of identified studies and reports.

2.2.1 Search strategy

The specific search strategy was designed to identify all relevant studies within the scope and focus as defined in the previous sections.

⁵ Examples of environmental impacts include effects on biodiversity, productivity and quality of the environment. Endocrine disrupting chemicals are examples of substances, which may have an impact on the reproductive system in living organisms in the environment. This may for example result in reduction in biodiversity.

- > A search of selected databases, including databases containing peer-reviewed literature, open literature and "grey" literature, was conducted with the purpose of locating research on health effects caused by exposure to chemicals and the related cost of this exposure.
- > Relevant studies conducted within the REACH restriction and authorization processes were obtained. Only those studies providing monetary valuations are included.

Search terms

The search was conducted using different search strings with a combination of search terms. The resulting studies were screened and selected based on their title (see section 3.2.2).

Figure 3-1 Illustrative overview of the search strategy. Not all search strings are included in the figure – see Appendix C for further information.

The search was conducted sequentially. Only the first 100 hits in the different databases were screened⁶.

The purpose has been to identify relevant valuation studies. It should be noted that the quality of the identified studies has not been reviewed. The user will have to make the assessment about the quality and usefulness of the each study.

See Appendix C for further information and literature search documentation.

2.2.2 Screening

In order to get a useful and relevant inventory of socio-economic valuation studies in the chemical field, some manual selection was necessary. A screening of abstracts was carried out with the purpose of increasing the relevance of the content for the users.

⁶ The 100 first hits were determined by the search engine by "relevance". In the pilot testing, more hits were reviewed and that did not lead to identifying more studies.

Three inclusion criteria The three inclusion criteria used to select for relevance in the review are described below.

- > To get the most relevant and up-to-date studies, only literature dating after 2005 were selected.
- > The selection focused on studies assessing the impact of chemicals use and exposure in developed countries. The database is primarily intended for users in the Nordic countries and other European countries and it is assumed that overall the "conditions" are most similar across developed countries compared to developing countries⁷.
- > Studies describing the full pathway, including chemical exposure⁸, health impact and the related social and economic costs, were selected.

**including emissions/exposure, impact and economic valuation*

Some studies not complying with all the three criteria were however considered to be of specific relevance, for example if they cover substances not otherwise included. These studies have been included in the database, though without the same level of details as the studies that fulfil all three criteria.

2.3 Grouping of substances and valuation methods

In order to provide the user with an overview of the studies and to make the database searchable, we have clustered chemical substances and valuation methods into groups. The groupings are described below.

⁷ It could be argued that some developing countries' exposure levels are much higher and that gives a basis for understanding the dose-response relations at high exposure levels.

⁸ It should be noted that studies focusing on health impacts caused by air pollution (e.g. exposure to NO_x, SO_x, particles etc.) were not included in the scope of study. These studies were mainly deselected based on the traditions of environmental policymaking where these air pollutants are managed by air quality units and not by the chemical policy units in most administration.

2.3.1 Chemical substances

One category used to group the selected studies is by name of the chemical substance valued, e.g. mercury, cadmium, bisphenol A. Studies where multiple substances were investigated or where the substances were not specified will be listed as 'multiple' or 'non-specified' respectively. If possible, they are grouped based on their common properties, effects or functions, for instance 'multiple heavy metals', 'multiple EDCs' or 'non-specified pesticides', respectively. If possible, the multiple substance names are stated as a comment in the database.

To support the searchability of the database, the different substances covered by the studies are further categorised based on the effect that is valued in the study in question.

The categorisation of substances is done based on the information from each study only. This means that even though a substance for instance is known to have endocrine disrupting properties, it will not be categorised as an endocrine disruptor if this property is not addressed and valued in the study in question.

The effect groups for the selected studies in the database are as follows:

- > Allergy
- > Carcinogenicity
- > Developmental toxicity
- > Endocrine disruption and reproductive toxicity
- > Neurodevelopmental toxicity
- > Neurotoxicity
- > Organ toxicity.

Effects on IQ as a result of prenatal exposure are categorised as neurodevelopmental, whereas effects on IQ from postnatal exposure, such as via contaminated foods are categorised as neurotoxic effects.

In case multiple effects are investigated, the effect group will be "multiple" and the specific effects are stated in a comment in the database.

2.3.2 Valuation of cost elements

The database contains information on the types of costs or benefits included in the valuation. Most studies include more than one cost or benefit element and each type of element may be estimated using different valuation methods. Therefore, the specific valuation method is not included directly. In most cases, the information is provided in one of the content fields. Valuations that did not fall into the three groups specified in the database were placed under 'Other' with a short explanatory text.

Groupings

The groupings are as follows:

- > Health care costs: Covers the costs of public health system and other public costs resulting from the exposure to chemical(s). Depending on the organisation of the health care system in different countries, some of these costs could be private costs (for example costs of medicine). The majority of studies include valuation of this cost element. We use the term to include also costs for special or extra education linked to reduced intellectual abilities caused by neurodevelopmental or neurotoxic effects of chemical exposure. Health care costs are typically estimated based on recorded expenditure.
- > Productivity loss: Covers both the loss in lifetime earnings and productivity loss associated with the production itself. For example, due to loss in IQ-points or sickness absence. This cost element is estimated using statistical data on personal incomes and the relationship between IQ and personal incomes⁹.
- > Welfare loss (sometimes called intangible costs): Covers the loss of personal welfare associated with increased sickness or risks of premature death. The welfare loss element is typically estimated using willingness-to-pay (WTP) approaches. WTP estimates may also include elements of health care costs and productivity losses.
- > Other: Valuation of costs elements that do not fit in the other groupings was placed under 'Other'.

2.4 Database content

Sheets

The database contains two sheets, including searchable information on the study's topic, method and results.

- > One sheet contains the selected sources with all the relevant information filled in.
- > Another sheet contains the list of identified studies that do not fulfil all the three criteria: published after 2005, cover developed countries and include the full impact pathway. In this sheet only the 'Basic info', 'Substance', 'Geography' and 'Study content' are filled in.

Headings

The database has been provided with headings that allow the user to find the most relevant studies. Each heading contains subheadings with further detailed information to make the database searchable. The heading and subheadings are shown below.

⁹ It is sometimes found to be estimated as part of WTP surveys. It seems not to be the case for any of the selected studies.

Basic info				Substance		Geography	
Author	Year	Publication type	Title	Substance	Effect group	Region	Country
Bartlett and Trasande	2013	Journal article	Economic impacts of environm	Multiple heavy metals	Multiple	Europe	Multiple
Bellanger et al.	2015	Journal article	Neurobehavioral deficits, dise	Multiple EDCs	Endocrine disruption	Europe	Multiple
Bellanger et al.	2013	Journal article	Economic benefits of methylm	Methylmercury	Neurodevelopmental	Europe	n/a
Bierkens et al.	2012	Journal article	Health impact assessment and	Lead	Neurotoxicity	Europe	Multiple
Bierkens	2013	Conference paper	Societal benefits from EU redu	Lead	Neurotoxicity	Europe	n/a
California Environmental Heal	2015	Report	Costs of environmental health	Multiple	Multiple	North America	USA
Forslund et al.	2010	Journal article	Does remediation save lives? (	Arsenic	Carcinogenicity	Europe	Sweden
Giang	2013	Master's thesis	Quantifying the health and ecc	Mercury	Multiple	North America	USA
Giang and Selin	2016	Journal article	Benefits of mercury controls fo	Mercury	Multiple	North America	USA
Gould	2009	Journal article	Childhood lead poisoning: Con	Lead	Neurotoxicity	North America	USA
Goyer et al.	2006	Article (Not published)	Health and economic impacts c	Formaldehyde	Multiple	North America	Canada
van Grinsven et al.	2010	Journal article	Estimation of incidence and so	Nitrate	Carcinogenicity	Europe	EU11

Impact								Valuation			
Heart disease	IQ	Obesity	Cancer	Fertility	Diabetes	Autism	Multiple	Health care costs	Welfare loss (WTF)	Productivity loss	Other costs
	x		x				Asthma	x		x	
	x					x	ADHD	x		x	
	x									x	
	x									x	
	x										Not informed
	x		x				Asthma	x		x	
			x						x		Valuation based
x	x							x		x	
x	x								x	x	
	x							x	x	x	
			x				Depending on th				The costs that co
			x						x		

Value transfer	Results	Study content	Reference
Note	Note	Abstract	Reference
Pathway: Data not directly presented. Refer to the study for pathway details. Pathway: Data and assumption for pathway assessment. Pathway: Assumption on all element of the pathway. Pathway: The study has estimated the pathway costs. Pathway: Limited details included. Refer to the study for details. Pathway: The study presents the key data and assumptions. Pathway: The article estimate the exposure and assessment. Pathway: Data and assessment presented. Pathway: Data on pathway assessment, e.g. health care costs. Pathway: Data available. The study focuses on the health care costs. Pathway: Data on exposure and effects presented. Pathway: Data and assumptions are presented.	The study makes estimates using a cost-of-illness approach. The study focuses on four exposure-outcome pathways: heart disease, IQ, obesity, and cancer. The total annual benefits of exposure prevention are estimated to be \$1.2 billion. The study uses the estimated effect of a 2.5% reduction in exposure. The paper combines the results of two EU reports. The report looks at the costs due to different exposure levels. The number of cancer cases from air inhalation is estimated to be 100 cases per year. The thesis conducts a case study of the Mercurius case. The study shows that by 2050, the Minamata Convention will reduce the net benefit of lead hazard control range from \$1.2 billion to \$0.5 billion. Depending on the new exposure limit value, the unit cost is obtained by dividing the health care costs by the number of cases.	ABSTRACT Background: There is increasing evidence of the role that exposure to environmental contaminants plays in the development of neurobehavioral deficits, diseases, and economic impacts. This study is a cost-benefit analysis that quantifies the health and economic impacts of lowering the total annual benefits of exposure prevention. ABSTRACT Context: Epidemiological studies and animal models demonstrate that exposure to environmental contaminants is associated with neurobehavioral deficits, diseases, and economic impacts. ABSTRACT Background: Due to global mercury pollution and the adverse health impacts of mercury, the European Union (EU) has implemented the Minamata Convention on Mercury. ABSTRACT A case study has been performed which involved the full chain of exposure assessment, health impact assessment, and economic impact assessment. ABSTRACT The current paper combines the results of two Sixth Framework Programme projects. ABSTRACT No abstract - But a summary. ABSTRACT Sweden has only just begun remediation of its many contaminated sites. ABSTRACT Mercury is a toxic pollutant that endangers human and ecosystem health. ABSTRACT Mercury pollution poses risks for both human and ecosystem health. ABSTRACT BACKGROUND: This study is a cost-benefit analysis that quantifies the health and economic impacts of lowering the total annual benefits of exposure prevention. ABSTRACT To evaluate the health and economic impacts of lowering the total annual benefits of exposure prevention, this study is a cost-benefit analysis that quantifies the health and economic impacts of lowering the total annual benefits of exposure prevention. ABSTRACT BACKGROUND: Presently, health costs associated with nitrate exposure are estimated to be \$1.2 billion per year.	Bartlett, E. S., & Trasande, L. (2013). Economic impacts of environmental contaminants: A review of the literature. <i>Environmental Health Perspectives</i> , 121(12), 1611-1620. Bellanger, M., Demeneix, B., Grandjean, P., Zoeller, R. T., & Tardieu, P. (2015). Neurobehavioral deficits, diseases, and economic impacts of exposure to environmental contaminants: A review of the literature. <i>Environmental Health Perspectives</i> , 123(12), 1211-1220. Bellanger, M., Pichery, C., Aerts, D., Berglund, M., Castaño, A., Bierkens, J., Buekers, J., Van Holderbeke, M., & Torfs, R. (2012). Health impact assessment and economic impact assessment of exposure to environmental contaminants: A review of the literature. <i>Environmental Health Perspectives</i> , 120(12), 1611-1620. Bierkens, J. G. E. A. (2013). Societal benefits from EU reduction of mercury exposure: A review of the literature. <i>Environmental Health Perspectives</i> , 121(12), 1611-1620. California Environmental Health Tracking Program, & Public Health Institute. (2015). <i>Childhood lead poisoning: Conservative estimates of the health and economic impacts of lowering the total annual benefits of exposure prevention</i> . Forslund, J., Samakovlis, E., Johansson, M. V., & Barregard, L. (2010). Does remediation save lives? A cost-benefit analysis of the health and economic impacts of lowering the total annual benefits of exposure prevention. <i>Environmental Health Perspectives</i> , 118(12), 1611-1620. Giang, A. (2013). Quantifying the health and economic impacts of mercury controls from air inhalation. <i>Environmental Health Perspectives</i> , 121(12), 1611-1620. Giang, A., & Selin, N. E. (2016). Benefits of mercury controls from air inhalation: A cost-benefit analysis. <i>Environmental Health Perspectives</i> , 124(12), 1611-1620. Gould, E. (2009). Childhood lead poisoning: Conservative estimates of the health and economic impacts of lowering the total annual benefits of exposure prevention. <i>Environmental Health Perspectives</i> , 117(12), 1611-1620. Goyer, N., Bégin, D., Bouchard, M., Carrier, G., Gérin, M., Lefebvre, J., & van Grinsven, H. J. M., Rabl, A., & de Kok, T. M. (2010). Estimation of the health and economic impacts of lowering the total annual benefits of exposure prevention. <i>Environmental Health Perspectives</i> , 118(12), 1611-1620.

The information presented in the columns on "Value transfer", "Results" and the "Abstract" contains more than one line of text. Two control buttons¹⁰ have been included to make the full text visible and to close it again.

Information presented Each study was assessed and brief notes where prepared. They include information about value transfer and the results. The below topics regarding the value transfer and results were taken into consideration when extracting data from the sources, to ensure a useful and user-friendly database.

Where available, the abstract have been copied into the database. The reference is included as a hyperlink to the where study can be found. It should be noted that journal articles might not be available without payment.

¹⁰ Require that the user enable macros in her/his Excel.

Table 3-1 Content of comments fields

TOPIC	Description
Value transfer	
Pathway > Exposure/concentration > Cohort	E.g. does the impact pathway start at soil concentration or blood concentration – pointing to what input data the user must have in order to apply the values from the study E.g. if the study focuses only on females aged 20-29
Cost/benefit information > Unit costs > Outliers > Method behind WTP figures	Is there e.g. a €/exposed person figure or do the user need to calculate one based on aggregated figures for total costs and total exposed population Very low/ high discount rate Reference to very old data Very low/high VSL or QALY Stated or revealed preference
Results	
Relative basis	What are the results relative to (country, region, capita, health hazard, tons emitted etc.)?
High-low	Reflecting scenarios or uncertainty

3 Findings and discussion

The review has identified 45 studies that fulfil the three selection criteria described in Section 3.3.2. These articles and studies are included in the Excel based database. The database format is described in Section 3.4 and illustrated by examples of the content in Appendix A.

3.1 Value transfer

The objective of creating the inventory of valuation literature has been to support policy analyses where monetary valuations would be needed or useful.

The review of studies consolidates information that can support value transfer as part of a policy assessment. It should be noted that for the majority of the reviewed studies, it is necessary to consult the study itself. To carry out the value transfer, the policy analyst needs to review the quality of the study and extract detailed information. It has been beyond the scope of this inventory and database to do a comprehensive assessment of all the identified studies.

When carrying out value transfer, several issues need to be considered. There are comprehensive guidance documents on how to do value transfer. For a recent overview, see Navrud (2016)¹¹. This overview also includes links to more elaborated guidance documents¹². Key points for consideration when doing value transfer include (Navrud 2016):

- 1 Identify the change in the good (effect) to be valued at the policy site
 - 1.1 Type of health impact
 - 1.2 Describe baseline, magnitude and direction of change
- 2 Identify the affected population at the policy site
- 3 Conduct a literature review to identify relevant primary studies
- 4 Assess the quality of study site values for transfer

¹¹ Navrud, S, 2016, *Possibilities and challenges in transfer and generalization of monetary estimates for environmental and health benefits of regulating chemicals*, OECD Workshop on socioeconomic impact assessment of chemicals management, ECHA, Helsinki July 6-8.

https://echa.europa.eu/documents/10162/22816069/stale_navrud_day2_presentation_en.pdf/35330650-82f4-430d-a58a-10f30717611d

¹² See for example: Söderquist, T and Å. Soutukorva (2006): *An instrument for assessing the quality of environmental valuation studies. Report*, Swedish Environmental Protection Agency;

Navrud (2006): *Benefit Transfer Guidelines*. Report to Danish Environmental Protection Agency;

Bateman et al (2009): *Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal. Value Transfer Guidelines*. Report to DEFRA.

- 4.1 Scientific soundness; the transfer estimates are only as good as the methodology and assumptions employed in the original, primary studies
- 4.2 Relevance; primary studies should be similar and applicable to the "new" context
- 4.3 Richness in detail; primary studies should provide a detailed dataset and accompanying information
- 5 Select and summarize the data available from the study site(s)
- 6 Transfer value estimate from study site(s) to policy site
 - 6.1 Determine the transfer unit
 - 6.2 Determine the transfer method for spatial transfer
 - 6.3 Determine the transfer method for temporal transfer
- 7 Calculate total benefits or costs
- 8 Assess uncertainty and acceptable transfer errors (and sensitivity analysis for size of "affected population")

An example can show the type of considerations that one needs to make when doing a value transfer.

As an illustrative example, we assume that we have a policy that aims to reduce the exposure to endocrine disruptors. The assessment would include a scenario where a policy measure would reduce the exposure of the population in one of the Nordic countries.

Using the database and filtering the studies that have addressed substances with endocrine disrupting effects results in a list of ten studies.

Author	Year	Publication type	Title	Substance		Geography	
				Substance	Effect group	Region	Country
Bellanger et al.	2015	Journal article	Neurobehavioral deficits, disease	Multiple EDCs	Endocrine disruption	Europe	Multiple
Hauser et al.	2015	Journal article	Male reproductive disorders, d	Multiple EDCs	Endocrine disruption	Europe	n/a
Health and Environmental Alli	2014	Report	Health costs in the European U	Multiple EDCs	Endocrine disruption	Europe	Multiple
Legler et al.	2015	Journal article	Obesity, diabetes and associat	Multiple EDCs	Endocrine disruption	Europe	n/a
Olsson et al. (Nordic Council o	2014	Report	The cost of inaction - a socioec	Multiple EDCs	Endocrine disruption	Europe	Multiple
Trasande	2014	Journal article	Further limiting bisphenol a in	Bisphenol A	Endocrine disruption	North America	USA
Trasande et al.	2016	Journal article	Burden of disease and costs of	Multiple EDCs	Endocrine disruption	Europe	Multiple
Trasande et al.	2015	Journal article	Estimating burden and disease	Multiple EDCs	Endocrine disruption	Europe	n/a
Hunt et al.	2016	Journal article	Female reproductive disorder,	Multiple EDCs	Endocrine disruption	Europe	n/a
European Chemicals Agency	2015	Report	Background document to the o	Bisphenol A	Endocrine disruption	Europe	n/a

Following the guidance principles above, the relevant primary valuation studies should be reviewed. The study or studies most appropriate for the policy assessment in question should be selected. The review of the selected valuation studies should include their scientific soundness, their relevance and their richness in details. The database does not include an evaluation of each study so the user will have to review the study based on the full study text.

Several of the studies have used the same data and approach (Ballenger et al 2015, Trasande *et al.* 2015 and Trasande *et al.* 2016). Trasande *et al.* 2016 is the most recent study and is an updated version of the two other studies

including one additional effect. Hence, this study includes the most comprehensive and recent estimate of the costs related to endocrine disrupting chemicals (EDCs). The study Olson et al. 2014 is specifically covering the Nordic countries and using data on effects and costs based on Nordic data. The Nordic study does on the other hand only include the effects on male reproduction and therefore is less comprehensive.

One point of complexity is to understand what the estimated costs relate to in terms of exposed population and the time-period for the exposure. One of the main effects is related to reduced IQ in exposed children. For example, the study Bellanger et al. 2015 presents the results as the cost for children born in 2010. This means that it is an estimate for the costs of one year of exposure. For other effects, increased risks of cancer as an example, it is less clear how the exposed population is defined. Here, the studies seem to have estimated the share of the current level of cancer cases that can be attributed to the exposure to EDCs.

Using the latest of the studies Trasande et al 2016, a value of the health costs of EDCs by EU Member States can be found. For the Nordic countries that are members of EU, the estimates are shown below.

The costs include the health care costs and the loss of income from sickness or premature death and from lower IQ. The loss of personal welfare – typically estimated using willingness to pay approaches – is not included in the estimation.

Table 4-1 Example of health costs from exposure to EDCs in Nordic countries

	Health costs of exposure to EDCs		
	Total costs in billion EUR per year	% of GDP	Per capita
Denmark	2.2	1.29	411
Finland	2.0	1.27	373
Sweden	4.0	1.34	426

Source: Trasande et al. 2016

The main cost element is exposure to organophosphate pesticides and the resulting loss of intellectual ability (measures by reduced IQ) accounts for about 75% of the total health costs. This cost element is estimated as the costs of exposure of the children in year 2010.

It is not clear what price level and discount rate(s) that have been applied. The costs at Member State level have been estimated using 2010 PPP adjusted GDP data so one could assume that the price level is 2010. Increasing to price level of 2016 could be done by using statistical data from Nordic Statistics, Eurostat or the national statistical offices.

The study has applied Monte Carlo simulations to assess the probabilities of the different costs levels. The result is that for EU28, there is 90% probability that costs are above 30 billion EUR and 10% probability that they are above 215 billion EUR. The median is 163 billion EUR per year. Applying this interval to the estimates for the three Nordic Member States gives the following results, presented in the table below.

Table 4-2 Uncertainty and sensitivity of health costs from exposure to EDCs in Nordic countries

	Health costs of exposure to EDCs in billion EUR per year		
	10%	Median	90%
Denmark	0.4	2.2	2.9
Finland	0.4	2.0	2.6
Sweden	0.8	4.0	5.3

Source: Trasande et al. 2016 and own calculations

Would these data be applicable to evaluate a policy in a Nordic country reducing the exposure to EDCs?

Following the guidance, the user would have to consider:

- > the quality and scientific soundness of these studies
- > the cost element covered that exclude the personal welfare loss element
- > the lack of certain details on discount rates and price level

When reviewing the studies in detail, it may be necessary to consult other material referenced in the studies as not all details on for exempling the costing are presented.

The sensitivity assessment suggests that correction for year of price level would have minor impact compared to the overall uncertainty.

If Trasande et al. 2016 would be assessed as suitable for value transfer in this example, the specific values have to be extracted. For chemical policy assessments, the unit relevant for value transfer is usually expressed as benefit per tons or kg of the substance in question, benefit per exposed person or benefit values per impacts caused by the exposure to the substance. For this study, there are values per country or per person in each country and these values could be applied; see the values for the included Nordic Countries in Table 4-1 above.

Navrud¹³ also provides suggestions on the level of uncertainty that one can accept depending on the use of the value transfer. He lists the following policy application where an increasing level of accuracy is needed:

- > Raising awareness of social costs
- > Cost-Benefit Analysis (CBA) of measures and regulatory frameworks
- > Environmental Accounting (adjusting national accounts)
- > Natural Resource Damage Assessment (NRDA) (calculating compensation payments after acute releases of chemicals)

Based on such guidance, the user of the database will have to determine whether the included studies can be used for value transfer. The studies on the impacts of endocrine disruptors seem to include a level of accuracy that makes them usable for raising awareness and possibly also for CBAs of measures and frameworks.

The example has illustrated some of the challenges of value transfer when the effects of exposure are complex regarding both the exposed population and the length of the exposure.

3.2 Data coverage and gaps

The literature search and the subsequent selection according to the inclusion/exclusion criteria resulted in 45 studies included in the database. The studies in the database included a total of 15 either distinct substances or substance groups. Out of the substances specifically mentioned by name, lead was the most studied, followed by mercury and methylmercury, i.e. substances all belonging in the 'heavy metal' substance group category. Figure 4-1 illustrates the substances or substance groups covered and the number of studies covering each substance or substance group.

¹³ Navrud, S, 2016, *Possibilities and challenges in transfer and generalization of monetary estimates for environmental and health benefits of regulating chemicals*, OECD Workshop on socioeconomic impact assessment of chemicals management, ECHA, Helsinki July 6-8. https://echa.europa.eu/documents/10162/22816069/stale_navrud_day2_presentation_en.pdf/35330650-82f4-430d-a58a-10f30717611d

Figure 4-1 Frequency of selected studies by substance or substance group¹⁴

The database covers a relatively limited amount of different substances. The number of studies included in the database is a result of the applied search strategy and the inclusion criteria. Whether a more balanced result could have been achieved if other, less restricted inclusion criteria had been applied is illustrated in the figure below. From this figure, it is evident that inclusion of deselected literature would result in the addition of other substances, but that the number of studies on these additional substances is limited to one or two studies. Lead is still the most commonly investigated substance in the identified literature (i.e. out of the gross literature list). However, in a large number of studies in the deselected literature, the actual substance is not specifically mentioned, but the majority (at least 30%) of these substances belong in the function group 'pesticide'.

¹⁴ The group called Multiple include one study covering: pesticides, lead, methyl mercury, PCBs, PBDEs, perchlorate

Figure 4-2 Frequency of deselected studies by substance or substance group

Based on their use and exposure patterns and known consumption, certain substance/function/effect groups, that have the potential to cause effects on human health, are missing or only included in a limited number of studies. This is the case for substances such as:

- > Flame retardants
- > Antimicrobials
- > Plasticisers
- > Respiratory allergens

Some chemicals belonging to these groups appear on the ECHA Candidate List of Substances of Very High Concern.

It should be noted, however, that some of these substances might be covered by the 'endocrine disruptor' effect group.

To ensure that the lack of identified studies was not a result of the search strategy (i.e. only reviewing the first 100 hits on each search engine), review of more than 100 hits for some of the search strings were conducted, which did not reveal any additional studies on the abovementioned substances.

3.3 Observations

The literature review has covered possible relevant literature very broadly as described above under research approach.

While there is a growing body of valuation literature, the review has revealed the following issues:

- > The main type of substances covered by monetary valuations are heavy metals. They are substances with substantial well-documented health effects and they have been subject to many assessments. An example is mercury where the studies include, as one of the main impacts, the neurological effects on the development of children and their cognitive abilities. The studies present the effect on the children's IQ and assess the health damage costs by using a unit value per IQ point that describes how much one IQ point affects lifetime income. The estimates are generally in line with each other. This might be due to use of the same primary sources. This is not clear from the studies as they often do not present all details but refer to other studies.
- > Valuations of endocrine disruptors are also covered by several studies. The issue of endocrine disrupting effects has more recently been recognised and the valuation studies are all relatively new (2014 to 2016). However, endocrine disruptors refer to a broad group of compounds, which can interfere with the endocrine systems and contribute to health impacts such as cancer, infertility, obesity, diabetes, birth defects, neurodevelopmental disorders, and reproductive problems. Several studies do therefore not include information about the specific identity of the substances but only refer to endocrine disruptors. In June 2016, the European Commission prepared a proposal for science-based criteria for determination of endocrine-disrupting properties for regulatory purposes.
- > Pesticides are another type of substances that have been subject to several monetary valuations. There are also many valuations in developing countries where handling of pesticides often causes serious health damage, but they have not been included in the database.

In relation to the use of the identified studies for value transfer, the following observations can be made:

- > All the selected studies include data on the full impact pathway. The challenge in terms of using them for value transfer is that often the studies do not present all the key data and assumptions in overview tables. The details are included in long text descriptions. Hence, it is often difficult to extract the assumptions used in the valuation for example to identify what is included in the applied unit damage costs. The user of the database will need to go to the studies and read them carefully to understand all assumptions, in order to achieve a correct value transfer.
- > The studies are often drawing on other previous studies for many of the assumptions, dose-response relations and unit values. These other studies are often only covering one element of the impact pathway. For example, studies that have estimated the value of certain health end-points. It might be necessary to consult such previous studies in order to understand all details of the applied values.

3.4 State of play

Overall, a very large number of studies have been screened through the comprehensive literature search. The review identified 45 studies that include monetary valuations of chemicals based on consideration of the impact pathway chain from emissions/exposure to valuation of human health impacts.

The studies can support policy assessment by providing unit values for value transfer. In most cases, the user will have to consult and read the study/report itself. The database includes information to identify the most relevant study or studies.

3.4.1 Evaluation of the search strategy

The specific approach to the literature search has advantages and disadvantages.

- Search results were only screened based on their title and short description – this may result in exclusion of studies with relevant data "hidden" within the content of the article or in supplementary information.
- The use of different terminology, especially regarding the different valuation terms, has been a point of attention when developing the search terms. Search terms and known abbreviations have been checked during the search phase. However, this may still have resulted in relevant references being overlooked if other wordings have been used in the specific study.
- The literature search was conducted in several databases with peer-reviewed literature, in environmental databases, from the bibliography of key reports, in the REACH restriction and authorisation dossiers, in the database for 'grey' literature and in Google. However, some documents, for instance European Commission Impact Assessments and reports from national authorities that could contain relevant information, may not necessarily be returned via the searches.

3.4.2 Suggestions for future updates

In order to update the database, the following literature sources may be relevant to include/check:

- Searches on cited references may be relevant. This includes new studies in which some of the key references included in the database have been cited.
- The Environmental Valuation Reference Inventory (EVRI), which is a compendium of summaries of studies providing contextualized monetary values of ecological goods and services. The focus of the database is, however, ecological goods and services, and not exactly in connection to

chemical exposure. Furthermore, it should be noted that the EVRI database is not available for users in the Nordic countries.

- > Searches for impact assessment related to chemical exposure from the European Commission.
- > Searches for impact assessment related to chemical exposure from national authorities in OECD countries.

It should be noted that some relevant Government and European Commission documents have been identified and included in the literature list.

Appendix A Extracts from database

Table overview		
Tables 1-4	4	Tables for different substances
Tables 5-11	7	Tables for different impacts
Tables 12-14	3	Tables for different regions

Table 1: Substance – Lead		
Author	Year	Title
Atherton et al.	2016	The value of reducing children's exposure to lead (Pb) A stated preference approach
Bierkens	2013	Societal benefits from EU reduction measures to decrease lead levels in the environment; Combining results from the EU funded projects INTARESE and HEIMTSA
Bierkens et al.	2012	Health impact assessment and monetary valuation of IQ loss in pre-school children due to lead exposure through locally produced food
European Chemicals Agency	2014	Background document to the opinion on the Annex XV dossier proposing restriction on lead and its compounds in articles intended for consumer use
European Chemicals Agency	2011	Background document to the opinion on the Annex XV dossier proposing restrictions on lead and its compounds in jewellery
European Commission	2012	Impact assessment study on health costs due to children's exposure to lead via toys and on the benefits resulting from reducing such exposure
Gould	2009	Childhood lead poisoning: Conservative estimates of the social and economic benefits of lead hazard control
Muennig	2009	The social costs of childhood lead exposure in the post-lead regulation era
Nevin et al.	2008	Monetary benefits of preventing childhood lead poisoning with lead-safe window replacement
Pichery et al.	2011	Childhood lead exposure in France: benefit estimation and partial cost-benefit analysis of lead hazard control

Table 2: Substance - Mercury / Methylmercury		
Author	Year	Title
Bellanger et al.	2013	Economic benefits of methylmercury exposure control in Europe: monetary value of neurotoxicity prevention
Giang	2013	Quantifying the health and economic impacts of mercury: an integrated assessment approach
Giang and Selin	2016	Benefits of mercury controls for the United States
Hylander and Goodsite	2006	Environmental costs of mercury pollution
Pacyna et al. (Nordic Council of Ministers)	2008	Socio-economic costs of continuing the status-quo of mercury pollution
Pichery et al.	2012	Economic evaluation of health consequences of prenatal methylmercury exposure in France
Rice et al.	2010	A probabilistic characterization of the health benefits of reducing methyl mercury intake in the United States
Spadaro and Rabl	2008	Global health impacts and costs due to mercury emissions
Sundseth et al.	2010	Economic benefits from decreased mercury emissions: Projections for 2020
Trasande et al.	2005	Public health and economic consequences of methyl mercury toxicity to the developing brain
Trasande et al.	2006	Applying cost analyses to drive policy that protects children: Mercury as a case study

Table 3: Substance - Pesticide		
Author	Year	Title
Pimentel	2005	Environmental and economic costs of the application of pesticides primarily in the United States
Tesfamichael et al.	2005	Risk-cost-benefit analysis of atrazine in drinking water from agricultural activities and policy implications
Travisi and Nijkamp	2008	Valuing environmental and health risk in agriculture: A choice experiment approach to pesticides in Italy

Table 4: Substance - Endocrine disruptor

Author	Year	Title
Bellanger et al.	2015	Neurobehavioral deficits, diseases and associated costs of exposure to endocrine-disrupting chemicals in the European Union
European Chemicals Agency	2015	Background document to the opinion on the Annex XV dossier proposing restriction on 4,4'-isopropylidenediphenol (Bisphenol A; BPA)
Hauser et al.	2015	Male reproductive disorders, diseases and costs of exposure to endocrine-disrupting chemicals in the European Union
Health and Environmental Alliance	2014	Health costs in the European Union: How much is related to EDCS?
Hunt et al.	2016	Female reproductive disorder, diseases, and costs of exposure to endocrine disrupting chemicals in the European Union
Legler et al.	2015	Obesity, diabetes and associated costs of exposure to endocrine-disrupting chemicals in the European Union
Olsson et al. (Nordic Council of Ministers)	2014	The cost of inaction - a socioeconomic analysis of costs linked to effects of endocrine disrupting substances on male reproductive health
Trasande	2014	Further limiting bisphenol a in food uses could provide health and economic benefits
Trasande et al.	2016	Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: an updated analysis
Trasande et al.	2015	Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European Union

Table 5: Impact – Heart disease

Author	Year	Title
Giang	2013	Quantifying the health and economic impacts of mercury: an integrated assessment approach
Giang and Selin	2016	Benefits of mercury controls for the United States
Nedellec and Rabl	2016	Costs of health damage from atmospheric emissions of toxic metals: Part 1 - Methods and results
Nedellec and Rabl	2016	Costs of health damage from atmospheric emissions of toxic metals: Part 2 - Analysis for mercury and lead
Rice et al.	2010	A probabilistic characterization of the health benefits of reducing methyl mercury intake in the United States
Trasande	2014	Further limiting bisphenol a in food uses could provide health and economic benefits

Table 6: Impact – IQ

Author	Year	Title
Atherton et al.	2016	The value of reducing children's exposure to lead (Pb) A stated preference approach
Bartlett and Trasande	2013	Economic impacts of environmentally attributable childhood health outcomes in the European Union
Bellanger et al.	2015	Neurobehavioral deficits, diseases and associated costs of exposure to endocrine-disrupting chemicals in the European Union
Bellanger et al.	2013	Economic benefits of methylmercury exposure control in Europe: monetary value of neurotoxicity prevention
Bierkens	2013	Societal benefits from EU reduction measures to decrease lead levels in the environment; Combining results from the EU funded projects INTARESE and HEIMTSA
Bierkens et al.	2012	Health impact assessment and monetary valuation of IQ loss in pre-school children due to lead exposure through locally produced food
California Environmental Health Tracking Program	2015	Costs of environmental health conditions in California children
European Chemicals Agency	2014	Background document to the opinion on the Annex XV dossier proposing restriction on lead and its compounds in articles intended for consumer use
European Chemicals Agency	2011	Background document to the opinion on the Annex XV dossier proposing restrictions on lead and its compounds in jewellery
European Chemicals Agency	2015	Background document to the opinion on the Annex XV dossier proposing restriction on 4,4'-isopropylidenediphenol (Bisphenol A; BPA)
European Commission	2012	Impact assessment study on health costs due to children's exposure to lead via toys and on the benefits resulting from reducing such exposure
Giang	2013	Quantifying the health and economic impacts of mercury: an integrated assessment approach
Giang and Selin	2016	Benefits of mercury controls for the United States
Gould	2009	Childhood lead poisoning: Conservative estimates of the social and economic benefits of lead hazard control

Table 6: Impact – IQ

Author	Year	Title
Health and Environmental Alliance	2014	Health costs in the European Union: How much is related to EDCS?
Hylander and Goodsite	2006	Environmental costs of mercury pollution
Muennig	2009	The social costs of childhood lead exposure in the post-lead regulation era
Nedellec and Rabl	2016	Costs of health damage from atmospheric emissions of toxic metals: Part 1 - Methods and results
Nedellec and Rabl	2016	Costs of health damage from atmospheric emissions of toxic metals: Part 2 - Analysis for mercury and lead
Nevin et al.	2008	Monetary benefits of preventing childhood lead poisoning with lead-safe window replacement
Pacyna et al. (Nordic Council of Ministers)	2008	Socio-economic costs of continuing the status-quo of mercury pollution
Pichery et al.	2012	Economic evaluation of health consequences of prenatal methylmercury exposure in France
Pichery et al.	2011	Childhood lead exposure in France: benefit estimation and partial cost-benefit analysis of lead hazard control
Pimentel	2005	Environmental and economic costs of the application of pesticides primarily in the United States
Rice et al.	2010	A probabilistic characterization of the health benefits of reducing methyl mercury intake in the United States
Spadaro and Rabl	2008	Global health impacts and costs due to mercury emissions
Sundseth et al.	2010	Economic benefits from decreased mercury emissions: Projections for 2020
Trasande et al.	2005	Public health and economic consequences of methyl mercury toxicity to the developing brain
Trasande et al.	2006	Applying cost analyses to drive policy that protects children: Mercury as a case study
Trasande et al.	2016	Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: an updated analysis
Trasande et al.	2015	Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European Union

Table 7: Impact – Obesity

Author	Year	Title
European Chemicals Agency	2015	Background document to the opinion on the Annex XV dossier proposing restriction on 4,4'-isopropylidenediphenol (Bisphenol A; BPA)
Health and Environmental Alliance	2014	Health costs in the European Union: How much is related to EDCS?
Legler et al.	2015	Obesity, diabetes and associated costs of exposure to endocrine-disrupting chemicals in the European Union
Trasande	2014	Further limiting bisphenol a in food uses could provide health and economic benefits
Trasande et al.	2016	Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: an updated analysis
Trasande et al.	2015	Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European Union

Table 8: Impact – Cancer

Author	Year	Title
Bartlett and Trasande	2013	Economic impacts of environmentally attributable childhood health outcomes in the European Union
California Environmental Health Tracking Program	2015	Costs of environmental health conditions in California children
European Chemicals Agency	2015	Background document to the opinion on the Annex XV dossier proposing restriction on 4,4'-isopropylidenediphenol (Bisphenol A; BPA)
European Chemicals Agency	2015	Background document to the opinion on the Annex XV dossier proposing restrictions on cadmium and its compounds in artist' paints
Forslund et al.	2010	Does remediation save lives? On the cost of cleaning up arsenic-contaminated sites in Sweden
Goyer et al.	2006	Health and economic impacts of lowering the occupational permissible exposure value for formaldehyde in Quebec: an overview of the approach
Health and Environmental Alliance	2014	Health costs in the European Union: How much is related to EDCS?

Table 8: Impact – Cancer

Author	Year	Title
KEMI	2015	Impact assessment of further regulation of Nanomaterials at a European Level
Nedellec and Rabl	2016	Costs of health damage from atmospheric emissions of toxic metals: Part 1 - Methods and results
Olsson et al. (Nordic Council of Ministers)	2014	The cost of inaction - a socioeconomic analysis of costs linked to effects of endocrine disrupting substances on male reproductive health
Pimentel	2005	Environmental and economic costs of the application of pesticides primarily in the United States

Table 9: Impact – Fertility

Author	Year	Title
European Chemicals Agency	2015	Background document to the opinion on the Annex XV dossier proposing restriction on 4,4'-isopropylidenediphenol (Bisphenol A; BPA)
Hauser et al.	2015	Male reproductive disorders, diseases and costs of exposure to endocrine-disrupting chemicals in the European Union
Health and Environmental Alliance	2014	Health costs in the European Union: How much is related to EDCS?
Hunt et al.	2016	Female reproductive disorder, diseases, and costs of exposure to endocrine disrupting chemicals in the European Union
Olsson et al. (Nordic Council of Ministers)	2014	The cost of inaction - a socioeconomic analysis of costs linked to effects of endocrine disrupting substances on male reproductive health
Trasande et al.	2015	Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European Union

Table 10: Impact – Diabetes

Author	Year	Title
Legler et al.	2015	Obesity, diabetes and associated costs of exposure to endocrine-disrupting chemicals in the European Union
Trasande et al.	2016	Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: an updated analysis
Trasande et al.	2015	Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European Union

Table 11: Impact – Autism

Author	Year	Title
Bellanger et al.	2015	Neurobehavioral deficits, diseases and associated costs of exposure to endocrine-disrupting chemicals in the European Union
Trasande et al.	2016	Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: an updated analysis
Trasande et al.	2015	Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European Union

Table 12: Geography - Europe

Author	Year	Title
Atherton et al.	2016	The value of reducing children's exposure to lead (Pb) A stated preference approach
Bartlett and Trasande	2013	Economic impacts of environmentally attributable childhood health outcomes in the European Union
Bellanger et al.	2015	Neurobehavioral deficits, diseases and associated costs of exposure to endocrine-disrupting chemicals in the European Union
Bellanger et al.	2013	Economic benefits of methylmercury exposure control in Europe: monetary value of neurotoxicity prevention
Bierkens	2013	Societal benefits from EU reduction measures to decrease lead levels in the environment; Combining results from the EU funded projects INTARESE and HEIMTSA
Bierkens et al.	2012	Health impact assessment and monetary valuation of IQ loss in pre-school children due to lead exposure through locally produced food
European Chemicals Agency	2014	Background document to the opinion on the Annex XV dossier proposing restriction on lead and its compounds in articles intended for consumer use
European Chemicals Agency	2011	Background document to the opinion on the Annex XV dossier proposing restrictions on lead and its compounds in jewellery
European Chemicals Agency	2015	Background document to the opinion on the Annex XV dossier proposing restriction on 4,4'-isopropylidenediphenol (Bisphenol A; BPA)

European Chemicals Agency	2012	Background document to the opinion on the Annex XV dossier proposing restrictions on chromium VI in leather articles.
European Chemicals Agency	2015	Background document to the opinion on the Annex XV dossier proposing restrictions on cadmium and its compounds in artist' paints
European Commission	2012	Impact assessment study on health costs due to children's exposure to lead via toys and on the benefits resulting from reducing such exposure
Forslund et al.	2010	Does remediation save lives? On the cost of cleaning up arsenic-contaminated sites in Sweden
Hauser et al.	2015	Male reproductive disorders, diseases and costs of exposure to endocrine-disrupting chemicals in the European Union
Health and Environmental Alliance	2014	Health costs in the European Union: How much is related to EDCS?
Hunt et al.	2016	Female reproductive disorder, diseases, and costs of exposure to endocrine disrupting chemicals in the European Union
KEMI	2015	Impact assessment of further regulation of Nanomaterials at a European Level
Legler et al.	2015	Obesity, diabetes and associated costs of exposure to endocrine-disrupting chemicals in the European Union
Nedellec and Rabl	2016	Costs of health damage from atmospheric emissions of toxic metals: Part 1 - Methods and results
Nedellec and Rabl	2016	Costs of health damage from atmospheric emissions of toxic metals: Part 2 - Analysis for mercury and lead
Olsson et al. (Nordic Council of Ministers)	2014	The cost of inaction - a socioeconomic analysis of costs linked to effects of endocrine disrupting substances on male reproductive health
Pichery et al.	2012	Economic evaluation of health consequences of prenatal methylmercury exposure in France
Pichery et al.	2011	Childhood lead exposure in France: benefit estimation and partial cost-benefit analysis of lead hazard control
Pizzol et al.	2014	External costs of cadmium emissions to soil: a drawback of phosphorus fertilizers
Trasande et al.	2016	Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: an updated analysis
Trasande et al.	2015	Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European Union
Travisi and Nijkamp	2008	Valuing environmental and health risk in agriculture: A choice experiment approach to pesticides in Italy
van Grinsven et al.	2010	Estimation of incidence and social cost of colon cancer due to nitrate in drinking water in the EU: a tentative cost-benefit assessment

Table 13: Geography – Global

Author	Year	Title
Pacyna et al.	2008	Socio-economic costs of continuing the status-quo of mercury pollution
Spadaro and Rabl	2008	Global health impacts and costs due to mercury emissions
Sundseth et al.	2010	Economic benefits from decreased mercury emissions: Projections for 2020

Table 14: Geography – North America

Author	Year	Title
California Environmental Health Tracking Program	2015	Costs of environmental health conditions in California children
Giang	2013	Quantifying the health and economic impacts of mercury: an integrated assessment approach
Giang and Selin	2016	Benefits of mercury controls for the United States
Gould	2009	Childhood lead poisoning: Conservative estimates of the social and economic benefits of lead hazard control
Goyer et al.	2006	Health and economic impacts of lowering the occupational permissible exposure value for formaldehyde in Quebec: an overview of the approach
Muennig	2009	The social costs of childhood lead exposure in the post-lead regulation era
Nevin et al.	2008	Monetary benefits of preventing childhood lead poisoning with lead-safe window replacement
Pimentel	2005	Environmental and economic costs of the application of pesticides primarily in the United States
Rice et al.	2010	A probabilistic characterization of the health benefits of reducing methyl mercury intake in the United States
Tesfamichael et al.	2005	Risk-cost-benefit analysis of atrazine in drinking water from agricultural activities and policy implications
Trasande	2014	Further limiting bisphenol a in food uses could provide health and economic benefits

Table 14: Geography – North America

Author	Year	Title
Trasande et al.	2005	Public health and economic consequences of methyl mercury toxicity to the developing brain
Trasande et al.	2006	Applying cost analyses to drive policy that protects children: Mercury as a case study

Appendix B Gross literature list

Peer-reviewed literature, studies, reports etc.

- Akerman, J., Johnson, F. R., & Bergman, L. (1991). Paying for Safety: Voluntary Reduction of Residential Radon Risks. *Land Economics*, 67, 435-446.
- Andersen, M. S., & Clubb, D. O. (2013). Understanding and accounting for the costs of inaction. In *Late lessons from early warnings: science, precaution, innovation* (pp. 564-580). European Environment Agency.
- Andersson, H., Tago, D., & Treich, N. (2014). Pesticides and health: A review of evidence on health effects, valuation of risks, and benefit-cost analysis. *Preference Measurement in Health (Advances in Health Economics and Health Services Research, Volume 24)*, 203 – 295.
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REACH-documents

Restriction dossiers on:

- > 1,4-Dichlorobenzene (p-dichlorobenzene)
- > 1-Methyl-2-pyrrolidone (NMP)
- > Ammonium salts
- > Bis(pentabromophenyl) ether (decabromodiphenyl ether) (DecaBDE)
- > Bisphenol A,4,4'-isopropylidenediphenol
- > Cadmium and its compounds (in Artist paints)
- > Chromium VI in leather articles
- > Chrysotile
- > DIBP, DBP, BBP, DEHP
- > Dimethylfumarate (DMF)
- > Lead and its compounds
- > Mercury
- > Methanol
- > Nonylphenol, branched and linear and Nonylphenol, branched and linear, ethoxylated

- > Perfluorooctanoic acid (and its salts)
- > Phenylmercury compounds

Guidance documents on how to do value transfer

Navrud, S, (2016), *Possibilities and challenges in transfer and generalization of monetary estimates for environmental and health benefits of regulating chemicals*, OECD Workshop on socioeconomic impact assessment of chemicals management, ECHA, Helsinki July 6-8

Söderquist, T and Å. Soutukorva (2006): *An instrument for assessing the quality of environmental valuation studies. Report*, Swedish Environmental Protection Agency

Navrud (2006): *Benefit Transfer Guidelines*. Report to Danish Environmental Protection Agency;

Bateman et al (2009): *Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal*. Value Transfer Guidelines. Report to DEFRA.

Appendix C Literature search documentation

The purpose of the literature search was to identify studies correlating and quantifying data on chemical exposures and health impacts and the related social and economic costs.

The studies have been identified through the following sources:

- > The project steering group
- > REACH documents
 - > Relevant studies conducted within the REACH restriction and authorisation processes were identified from Annex XV dossiers and documents from the authorization processes from ECHAs homepage.
- > The UNEP report "Cost of Inaction on the Sound Management of Chemicals"
 - > The reference list from the report was screened in order to identify relevant studies based on their title.
- > Environmental databases
 - > Nordic environmental valuation database (NEVD): the reference list was screened in order to identify relevant studies based on their title
 - > Valuebase^{SWE}: The titles of the studies contained in the database was screened in order to identify relevant studies
- > Peer-reviewed literature
 - > Searches according to below mentioned search strategy was conducted in several databases
- > Open-source literature
 - > Searches according to below mentioned search strategy was conducted in Google

Search strategy

A search of the databases: ScienceDirect, Web of Science and Google Scholar was conducted in April and May 2016 for the purpose of locating published research on health effects caused by direct exposure to chemicals and the related cost of this exposure. A database belonging to a Danish University (DTU Findit) was also searched.

A Google search and a search in SIGLE (System for Information on Grey Literature in Europe) was also conducted to identify any other relevant documents or reports published.

Inclusion/exclusion criteria

Inclusion criteria for this data search was studies that include the "full" impact pathway, i.e. including exposure, health impact and economic valuation. This was, however, not always evident from the title, so the search results may also include studies and references where the full impact pathway has not been covered. These references were deselected in the review phase.

Exclusion criteria: cost of illness studies, all studies focussing on air pollution, such as NO_x, SO_x etc. including particulate matter, studies focussing on pollution in general, where no direct exposure to chemicals is evident.

List of search terms

Following search terms were used to search the databases with the article title, abstracts and body all being searched. The searched synonyms are mentioned in brackets.

> Chemical(s)

In combination with:

- > Health cost
- > Monetary valuation or valuation or monetary
- > Willingness to pay (WTP)
- > Quality Adjusted Life Years (QALY)
- > Value of Statistical Life (VSL)
- > Cost of exposure
- > Cost of late action or inaction
- > External cost or externalisation
- > Impact pathway
- > Value of Life Year (VOLY)

Additional searches on specific chemical groups, chemicals etc. were subsequently conducted in Google Scholar, in combination with the search terms above that resulted in most hits in the first search phase.

Following terms were used:

- > Endocrine disruptors
- > Heavy metals
 - > Lead, Cadmium, Methyl mercury
- > Carcinogen
- > Allergy/allergen

- > Biocides
- > Bisphenol A

Procedure

The search was conducted sequentially using the abovementioned search engines and search terms and the results are documented in the tables below. The resulting articles were screened based on their title and selected according to matches between the title and the inclusion criteria/search terms. Only the first 100 hits were screened.

Studies are only registered once even though they may appear from several different searches using different search terms.

The articles identified in this phase of the literature search have not been examined according to publication year and geography and the resulting number of articles shown in the tables are thus the gross list of literature identified.

ScienceDirect includes a feature, where three additional papers are shown under the headline "Other users also viewed these articles" after selection of a specific paper – these titles are also reviewed and included in the selection if found relevant.

Results

The search of the selected databases and regular google searches resulted in the retrieval of 110 papers. The SIGLE yielded no papers.

The gross list of identified references, including references from the other sources of literature is found in Appendix B.

Search engine	Search terms	# Retrieved out of the first 100 hits (total number in bracket)
ScienceDirect	Chemical* AND "health cost"	3 (1,390) Additional papers retrieved: 2
Web of Science		0 (4)
Google Scholar		6 (3,600)
University database (DK)		1 (3)
ScienceDirect	Chemical* AND monetary valuation	4 (2,571) Additional papers retrieved: 1
Web of Science		0 (9)
Google Scholar		2 (32,700)
University database (DK)		No hits
ScienceDirect	Chemical* AND valuation	1 (11,066)
Web of Science		0 (235)
Google Scholar		1 (123,000)
University database (DK)		0 (50)
ScienceDirect	Chemical* AND WTP or Willingness to pay	1 (4,124)
Web of Science		4(140)
University database (DK)		0 (16)
Google Scholar	Chemical* "Willingness to pay" ²	2 (36,400)
ScienceDirect	"Cost of exposure"	1 (91) Additional papers retrieved: 1
Web of Science		1 (22)
Google Scholar		1 (724)
University database (DK)		5 (88 ¹)
ScienceDirect	"Health effect" AND valuation	0 (249)
ScienceDirect	Chemical* AND "health benefits" For google scholar: chemical* "health benefits" cost valuation	0 (18,546)
Web of Science		0 (2,297)
Google Scholar		1 (21,000)
University database (DK)		0 (162)
ScienceDirect	Chemical* AND "economic benefits"	0 (15,508)
Web of Science		2 (526)
Google Scholar		3 (116,000) Additional papers retrieved: 2
University database (DK)		1 (60)
ScienceDirect		0 (37)

Web of Science	Chemical* AND "cost of inaction"	0 (1)
Google Scholar		1 (1,150)
University database (DK)		No hits
ScienceDirect	Chemical* AND "cost of late action"	No hits
Web of Science		No hits
Google Scholar		1 (15)
University database (DK)		No hits
ScienceDirect	Chemical* AND "Quality Adjusted Life Years" OR QALY) For google scholar: chemical* QALY "Quality Adjusted Life Years"	1 (687)
Web of Science		0 (6)
Google Scholar		0 (4,300)
University database (DK)		0 (15)
ScienceDirect	(Chemical* AND ("value of statistical life" OR VSL)) For google scholar: chemical* "value of statistical life"	1 (2,965)
Web of Science		1 (26)
Google Scholar		2 (1,440)
University database (DK)		Additional papers retrieved: 2
ScienceDirect	Chemical* AND "impact pathway"	4 (173)
Web of Science		0 (5)
Google Scholar		1 (1,810)
University database (DK)		0 (3)
ScienceDirect	Chemical* AND "external costs"	1 (1,550)
Web of Science		0 (15)
Google Scholar		2 (17,600)
University database (DK)		0 (2)
ScienceDirect	Chemical* AND externalit*	0 (6,389)
Web of Science		2 (62)
Google Scholar		2 (18,400)
University database (DK)		No hits
ScienceDirect	Chemical* AND "Value of Life Year" OR VOLY	1 (98)
Web of Science		0 (1)
Google Scholar		1 (103)

University database (DK)	For Google Scholar: Chemical* "Value of Life Year"	0 (1)
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¹ Not all references are unique references.

² WTP was not searched in this string in order to exclude irrelevant hits for "Water Treatment Plant" (Google Scholar do not operate with Boolean)

Additional searches on specific chemical groups or effects:

Search engine	Search terms	# Retrieved out of the first 100 hits (total number in bracket)
Google Scholar	Endocrine disrupt* AND "health costs"	3 (2,430) Additional papers retrieved: 2
	Endocrine disrupt* AND "costs of exposure"	1 (162)
	Endocrine disrupt* AND "economic benefit"	0 (2,890)
	Heavy metal AND "health costs"	1 (12,800)
	Lead AND costs of exposure	4 (3,000,000)
	Methyl mercury AND cost of exposure	3 (56,400) Additional paper: 1
	Methyl mercury economic benefits	3 (26,500)
	Cadmium AND cost of exposure	0 (108,000)
	Arsenic "health costs"	2 (2,440)
	Arsenic cost of exposure	1 (66,900)
	Biocide* "Health costs"	1 (330)
	Nickel cost of exposure allerg*	1 (15,100)
	Phthalate* cost of exposure	0 (27,600)
	Phthalate* willingness to pay	0 (1,170)
	Phthalate* "external cost"	1 (34)
	Phthalate* DAILY QALY	0 (23)
	"Flame retardants" "costs of exposure"	0 (38)

	"Flame-retardant" "costs of exposure"	0 (22)
	"Flame retardants" monetary valuation	0 (1,190)

Search engine	Search terms	# Retrieved out of the first 100 hits	Date
Google	Monetary valuation chemical effects	15	18 May 2016
	Health costs chemicals	2	18 May 2016
	Costs of exposure chemicals	0	18 May 2016
	"cost of chemical exposure"	0	18 May 2016
	chemical impact pathway	0	18 May 2016
	impact pathway chemical exposure	0	18 May 2016
	Economic benefit chemical exposure	0	18 May 2016
	Socio-economic costs chemicals	1	23 May 2016
	external costs chemical exposure	0	24 May 2016

Search engine	Search terms	# Retrieved out of the first 100 hits (total number in bracket)
SIGLE (opengrey.eu)	Monetary Valuation	0 (18)
	Costs of exposure	0 (55)
	Health costs chemical	0 (13)
	Socio-economic impact chemical	0 (4)
	Quality adjusted life years	0 (14)
	Endocrine disruptor	0 (20)
	Willingness to pay	0 (131)
	Valuation effects	0 (71)