Chemicals for a sustainable future

Report of the EEA Scientific Committee Seminar

Copenhagen, 17 May 2017

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European Environment Agency

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This report was drafted by Xenia Trier, Catherine Ganzleben and Ybele Hoogeveen, and it was revised in accordance with comments provided by the participants at the *Chemicals for a sustainable future* Scientific Committee seminar.

Preface

The European Environment Agency (EEA) Scientific Committee assists the Management Board and the Executive Director of the EEA in providing advice on scientific matters of relevance to the Agency's work. The Scientific Committee is composed of independent scientists, recruited through an open call for expressions of interest covering a variety of environmental fields.

This advisory role is realised, in part, through regular EEA Scientific Committee seminars, where the Scientific Committee members, EEA staff and selected external experts and stakeholders explore emerging and cross-cutting issues of relevance to the work of the EEA and the European Union's environmental policy agenda.

This report documents the outcomes of the EEA Scientific Committee seminar, Chemicals for a sustainable future, held at the EEA in Copenhagen, Denmark, on 17 May 2017. The focus was on the knowledge base for identifying, assessing and governing the impacts of chemicals on humans and the environment.

The views and opinions of the seminar participants as documented here do not necessarily reflect a formal position of the EEA.

Previous EEA Scientific Committee seminars have focused on the following topics:

- *Environment, health and wellbeing* (February 2014);
- *The European environment — State and outlook 2015* (May 2014);
- *Ecosystems and their services — Building the knowledge base for European assessments* (October 2014);
- *Living well within the limits of the planet, EU knowledge base prospects* (February 2015);
- *Use of the underground* (June 2015);
- *Emerging systemic risks* (February 2016);
- *Knowledge for transitions* (May 2016);
- *Land as a resource* (October 2016).

Abbreviations

BFR	Brominated flame retardant
CFC	Chlorofluorocarbon
CLP	Classification and Labelling of Products
DALY	Disability-Adjusted Life Years
DG ENV	Directorate-General, Environment
DG GROW	Directorate General, Internal Market, Industry, Entrepreneurship and Small and Medium-sized Enterprises
DG JRC	Joint Research Centre
EAP	Environment Action Programme
ECEHH	European Centre for Environment and Human Health
ECHA	European Chemicals Agency
EDC	Endocrine-disrupting chemical
EEA	European Environment Agency
EU	European Union
F-gas	Fluorinated gas
GDP	Gross domestic product
GHG	Greenhouse gas
HBCDD	Hexabromocyclododecane
HBM4EU	Human Biomonitoring for Europe
HEAL	Health and Environment Alliance
IQ	Intelligence quotient
KEMI	Swedish Chemicals Agency
LRTAP	Long Range Transboundary Pollution

NILU	Norwegian Institute for Air Analysis
NOTES	Non-toxic Environment Strategy
ODS	Ozone-depleting substance
PBT	Persistent, bioaccumulative and toxic
PCB	Polychlorinated biphenyl
PFAS	Poly- and perfluoro alkyl substance
PFOS	Perfluorooctane sulfonate
PM	Persistent and mobile
PMT	Persistent, mobile and toxic
POP	Persistent organic pollutant
PPPR	Plant Protection Product Regulation
R&I	Research and innovation
REACH	Registration, Evaluation, Authorisation and Registration of Chemicals Regulation
REFIT	Regulatory Fitness and Performance
SAICM	Strategic Approach to International Chemicals Management
SDG	Sustainable Development Goal
SDU	University of Southern Denmark
SVHC	Substance of very high concern
vPvB	Very persistent and very bioaccumulative
vPvM	Very persistent and very mobile
WHO	World Health Organization

Key messages from the seminar

What is at stake?

1. Chemical production is increasing and poses risks to ecosystems and human health

People and wildlife are exposed to mixtures of chemicals from consumer and medicinal products and through contaminated water, food, air and soil. Human health effects include cancer, decreased fertility, allergies, diabetes, depression, dementia and stress, and respiratory, cardiovascular and skin diseases. Environmental effects include the degradation and loss of function of ecosystems and their services. The diversity and quantity of synthetic chemicals in use has increased rapidly ([i]), to approximately 100 000 industrial substances. Globally, chemical production has grown 50-fold since 1950 ([xxiii]), and it is set to triple again by 2050 compared to 2010, mainly outside Europe ([ii]).

2. European legislation has reduced acute pollution, but chronic, less apparent effects persist

European legislation has reduced much acute chemical pollution over the past 50 years, in the environment and in the workplace, but hazardous chemicals continue to affect the long-term human health and ecosystem resilience, in Europe and globally.

Pollution is the number one burden of disease globally, with air pollution alone causing the premature death of 6.5 million people per year ([xi]). In Europe, it accounts for 467 000 premature deaths ([iii]), while carcinogens account for more than 100 000 work-related deaths, corresponding to 53 % of the total ([xvii]). Examples of more hidden pollution are exposure to complex mixtures of chemicals in consumer products, exposure to endocrine, neuro- or immuno-developmental toxic chemicals during pregnancy (causing intergenerational effects), and the impacts of EU chemical production and discharges on people and ecosystems outside the EU, e.g. in the Arctic.

3. Environmental and societal megatrends are changing exposure patterns

Climate change causes more frequent and extreme weather events, which in turn aggravate chemical pollution. Effects include storms and flooding remobilising hazardous chemicals from landfills, droughts increasing chemical concentrations in water and fires increasing air pollution. Megatrends also play a role: the combined trends of urbanisation and ageing, for example, have led to an increasing proportion of the EU population living in densely populated areas with increasing exposure, and enhanced vulnerability, to multiple environmental pressures.


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Research and innovation

4. Chemical risks are traditionally underestimated by science

An understanding of the impact of individual and mixtures of chemicals has developed gradually over the past 60-70 years. Nevertheless, science, driven by funding of academic traditions and individual career perspectives, tends to be biased towards known risks, deepening knowledge of the 'usual suspects' rather than exploring the big unknowns regarding the majority of lesser-studied chemicals. Broadening research to address the impacts of a wider range of chemicals in the environment, as well as the impacts of chronic, low-level exposure to chemical mixtures during critical developmental periods, would help close the gap around lesser-known risks.

5. Green and sustainable chemistry requires targeted innovation

The transition to a low-carbon circular economy provides excellent opportunities for boosting safe and environmentally sustainable chemistry. The focus of innovation should be 'safe by design' — products compatible with clean material cycles, using fewer and less harmful chemicals. Examples include the adoption of green chemistry principles for chemical production, ecodesign, non-chemical solutions and leasing business models. This requires interdisciplinary collaboration between designers, chemists, down-stream industries and users, as well as authorities, supported by dedicated EU research and innovation (R&I) expenditure, across research areas, as also highlighted in the European Chemicals Agency (ECHA)'s recent 'Strategy to promote substitution to safer chemicals through innovation' [iv] ([1]). Educating the next generation of chemists and product developers will be key to integrating principles of safe-by-design and sustainable chemicals in the design phase [v].

Risk assessment

6. A focus on critical parameters is more important than gathering more general data

The implementation of REACH (Registration, Evaluation, Authorisation & restriction of CHemicals) has generated much knowledge, but the toxic effects of many chemicals, especially mixtures, have not been assessed. Comprehensive risk assessments are time consuming, costly and do not necessarily ensure more solid results. Prioritisation and alternative monitoring approaches are needed, as well as wider application of the precautionary principle in risk assessments. Critical properties of chemicals are typically persistency,

([1]) The key elements of ECHAs 'Strategy to promote substitution to safer chemicals through innovation' are: 1. Capacity building along the supply chain; 2. Funding and technical support for substitution initiatives; 3. Using ECHA's chemicals data more efficiently; and 4. Developing coordination and collaboration networks.
https://echa.europa.eu/documents/10162/13630/250118_substitution_strategy_en.pdf/bce91d57-9dfc-2a46-4afd-5998dbb88500

mobility, bioaccumulation and toxicity. Through a combination of data sets and read-across techniques, viable groups of chemical families could be identified and assessed. This could also help prevent regrettable substitutions.

7. Monitoring for a wider variety of chemicals can provide earlier warnings

Chemicals typically turn out to be more harmful than initially thought as long-term effects emerge and knowledge expands. Emerging risks could be detected earlier by monitoring a wider variety of priority chemicals in fast-responding media such as air and water. Human biomonitoring could reveal the total chemical burden from combined sources and explore their causal effects on human health.

Risk management

8. Policy approaches need to be further integrated in support of sustainability objectives

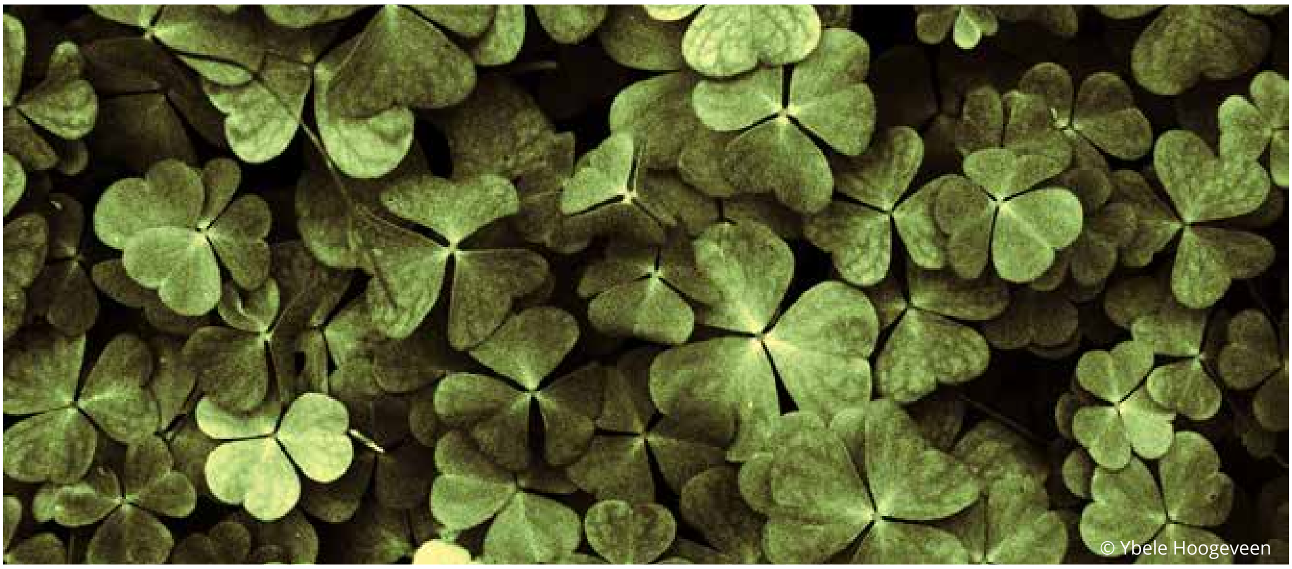
EU legislation regarding chemicals typically addresses separate environmental media, individual substances and their specific uses. To deal with the overall environmental burden of chemicals on human and ecosystem health, broader approaches are needed. Assessing risk and impacts across the life cycles of chemicals, including on ecosystem services and resilience, would provide more relevant results. Overall, further EU policy integration can help to achieve an overall sustainability of chemicals in relation to toxicity, energy and resource efficiency. Legal standards for the design of safer products should also be further developed.

9. Avoiding upstream use of persistent and hazardous chemicals is key

Persistent substances remain in ecosystems for decades, and exposure via contaminated resources may impact the health of future generations. This is particularly problematic for recycled materials, in which hazardous chemicals are difficult, costly and time consuming to trace and remove. Indeed, transitional adaptation measures may be needed to remove contaminated materials from the material stream in order to obtain sufficiently clean material cycles. Going forward, focusing on reducing complexity and essential uses, rather than on convenient ones, could help reduce the overall consumption of persistent and hazardous chemicals. Regulation, in tandem with economic instruments and awareness raising, could be the most effective way of reducing and preventing the use of chemicals of concern as well as driving investment towards the development of a sustainable chemical production infrastructure.

10. A less toxic environment requires visionary and inclusive stakeholder approaches

Chemicals benefit lifestyle, the economy, agriculture and medicine. Yet, they also constitute increasing and insufficiently recognised or understood risks to the health of both people and the environment. To catalyse a fundamental transition to a less toxic, safe and sustainable future, we need a compelling and practical vision of the future we want, one that minimises risks to health and the environment while maximising opportunities for innovation, economic development and jobs. Developing such a vision must involve all stakeholders: businesses across the supply chain, civil society, non-governmental organisations, legislators and both natural and social scientists.



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Introduction

This report provides a summary of a European Environment Agency (EEA) Scientific Committee seminar, *Chemicals for a sustainable future*, held at the EEA in Copenhagen, Denmark, on 17 May 2017. Participants in the seminar considered the knowledge base for identifying, assessing and tackling the impacts of chemicals on humans and the environment.

Discussions at the seminar were set within the framework of the General Union Environment Action Programme to 2020 ([vi]), also referred to as the Seventh Environmental Action Programme (7th EAP). The 7th EAP is intended to guide action on the environment up to and beyond 2020, and it sets out the ambition that by 2050 we will live well within the limits of the planet. At the same time, it commits the European Union (EU) to transitioning to a green, circular and low carbon economy. As a means to achieve this goal, the 7th EAP calls for a strategy for a non-toxic environment by 2018, focusing on vulnerable groups, regulatory approaches to address combination effects of chemicals, minimisation of exposure to chemicals in new and recycled products and to endocrine disrupters, and improved safety of nanomaterials.

In their conclusions of 19 December 2016 ([vii]), the Environment Council of the EU noted with concern that these measures had not yet been undertaken, and emphasised the need to develop a long-term vision on future sound management of chemicals and waste linked to the broader international policy agenda, including the Strategic Approach to International Chemicals Management ([viii]) (SAICM) and the United Nations' 2030 Sustainable Development Agenda ([ix]).

Achieving these ambitions will require transitions in systems of production and consumption in order to address the drivers that keep generating increasing amounts of chemicals of concern. If chemicals of concern are regulated, they are currently addressed in legislative 'silos', not considering the full life cycle of chemicals, or constraints, because of resource scarcity, planetary boundaries, climate change or combined effects on humans or the environment. Transitions offer significant opportunities to re-invent our systems to address both complex health and environmental risks, as well as emerging societal challenges (e.g. resource efficiency, clean material cycles in a circular, low-carbon and bio-economy), while giving Europe a competitive innovative edge in the use of sustainable chemicals, products and business models.

The EEA Multiannual Work Programme ([x]) responds to the 7th EAP and frames the EEA contribution under three strategic areas. **Strategic area 1** focuses on providing information to support implementation of both established and emerging policy frameworks. A number of areas under **Strategic area 1** explicitly tackle risks to human health via the environment, including air pollution, transport and noise pollution; industrial pollution; climate change impacts, vulnerability and adaptation; and water resources and aquatic ecosystems.

Objectives of the seminar

The overall objectives of the seminar were for participants to engage in a discussion on current and anticipated chemical risks and hazards across society, and how these can be minimised through different actions and thereby contribute to a transition towards sustainability in Europe. In doing so, the expectation was to guide the EEA on where to focus developments in knowledge in this domain in the coming years.

This should be seen in a context in which the EEA is calling for a transition towards a green economy in its latest 5-year report published in March 2015 — *The European environment —State and outlook 2015* (SOER 2015) ([xi]). The profound changes involved in a systemic transition provide opportunities to secure long-term sustainability, halt environmental degradation and increase human wellbeing. How society produces and uses chemicals will be fundamental to the success of such a transition.

Participants at the seminar were invited to reflect on how we, as a society, identify and balance emerging risks and opportunities and their distribution against social, economic and governance objectives.

The debates served to inform the Agency's ongoing work on chemicals in support of EU policy developments such as the Non-toxic Environment Strategy (NOTES), and the outcomes will be targeted towards helping the EEA improve its knowledge in this domain in the run-up to the 2020 report, *The European environment — State and outlook 2020* (SOER 2020). Prior to the seminar, a background document was produced and shared with the participants to provide context and information to enable seminar participants to understand the many aspects of chemical pressures on humans and the environment. It summarises a few of the issues at stake and possible solution pathways and tools in terms for the non-expert.

Specific objectives for the seminar included the following:

- learning from experts and practitioners what is at stake in relation to chemical pollution, and key scientific challenges;
- learning from policymakers, experts and practitioners which strategic options, approaches, processes and tools could be applied to respond to chemical risks to humans and the environment;
- receiving input from our Scientific Committee and from the participants on which areas might have most impact for the EEA to work on, with the aim of informing how the EEA can build knowledge to support EU policies and the NOTES.

Structure of the seminar

The seminar was organised around two sessions, entitled:

- Session 1: What is at stake? Key scientific insights
- Session 2: How to respond? Strategic options

In each session, a number of experts provided presentations. These were then followed by a panel discussion, consisting of the speakers and three additional expert panel members. The additional panel members were given the opportunity to reflect for 3-5 minutes on the presentations in their session. Following this, the Scientific Committee members and guests were invited for an open discussion, mediated by the co-chairs, Hans Bruyninckx, EEA Executive Director, and Per Mickwitz, Chair of the EEA Scientific Committee.

This meeting report provides a summary of the presentations and discussions structured in accordance with the programme of the workshop (see Annex 1), including opening remarks, the two sessions and concluding remarks.

Opening remarks

Per Mickwitz, Chair of the EEA Scientific Committee, opened the seminar and welcomed participants. He noted that chemicals are essential in society and are incorporated into a range of products on which we depend. Chemicals have the capacity to both enhance and degrade human health and the move towards a circular economy. We need to handle chemicals in this context. He recognised the depth and diversity of the knowledge in the room and anticipated high-quality discussions on the issue of sustainable chemicals.

Hans Bruyninckx, EEA Executive Director, reminded us that we have to be big on the big things, small on the small things, and that managing chemicals is a big thing. The chemicals sector is economically important and a major source of innovation in Europe, enhancing the global competitiveness of the EU. Meanwhile, the EU has been early to develop environmental policies focused on fighting chemical pollution, which today have shifted towards recognising more complex problems, such as exposure to mixtures of chemicals, and an evolved understanding of toxicity, such as low-dose effects of endocrine disrupters. The chemicals theme runs across the three key objectives of the 7th EAP: protecting natural capital, the low-carbon economy and environmental risks to health. The EEA works on these dimensions in a wide range of activities, spanning from application of the precautionary principle and management of chemicals in the circular and low-carbon economies to environmental and human biomonitoring. Knowledge is essential to making sound decisions, and for chemicals there is still much that we do not know. He welcomed the opportunity for this scientific seminar to start a serious debate on where to take the knowledge component of chemicals policies in Europe.

Session 1: What is at stake? Key scientific insights

Chemicals and the environment in Europe

Presentation by Xenia Trier (EEA)

Xenia Trier described how the EEA collaborates with an extensive network to gather, synthesise and translate knowledge for policy support. Chemicals cut across many of the EEA domains and EU policy areas, whether as pollutants assessed in air, water, soil, impacts from agrochemicals and transport, or as ozone-depleting substances (ODSs) and greenhouse gases (GHGs) linked to climate change.

Historically, European environmental policy has often been shaped in response to acute, visible and deadly pollution ([xii]), e.g. the 1952 London smog, the 'Minamata disease' caused by methylmercury and discovered in 1956 in Japan, the 1980s acid rain devastating European forests, or the 1976 Seveso dioxin pollution disaster. Policy responses have typically addressed specific substances, environmental media and sectors, and have been generally successful in reducing pollution, whereby substantial costs to the environment and health have been avoided ([xiii]). Many Europeans therefore consider the risks to be lower today than before.

However, the invisible, complex and less immediate effects of chemical pollution remain a public concern, particularly in northern Europe where awareness is high. The most acute chemical pollution effects are well documented: globally, air pollution kills an estimated 6.5 million people per year and is the number one cause of disease ([xiv]). In Europe, air pollution is estimated to cause disease to just below 0.5 million Europeans ([iii]). Cancer is the first cause of work-related deaths in the EU, accounting for 53 % of the total, compared with 28 % for circulatory diseases and 6 % for respiratory diseases. In total, 102 500 deaths per year are attributed to occupational cancer in the EU ([xv,xvi,xvii,xviii,xix]).

Recently, a series of new studies argued that pollution may cause up to three times more deaths than malaria, AIDS (acquired immune deficiency syndrome) and tuberculosis combined ([xx]). These studies include exposure to low levels of (known) chemicals during the critical fetal development stage, linked to lower birth weight ([xxi]), impaired development of the brain, lungs and immune systems of the babies, and to a long list of disabling and fatal diseases later in life ([xxii]). The associated costs to societies in the EU, United States and Organisation for Economic Co-operation and Development (OECD) countries has been estimated to be up to 10 % of the gross domestic product (GDP) ([xxii,xxiii]). Since reliable safety data are lacking for the estimated 85 000 industrial chemicals used globally ([xxiv]), it is likely that the real health impacts of chemicals are underestimated ([xxiv]).

Xenia Trier went on to explain that risk is a combination of chemical hazard (toxicity) and exposure:

$$\text{Risk} \propto \text{Hazard} \times \text{Exposure}$$

High risk is typically caused by toxic and persistent chemicals, as persistency leads to high body burdens or levels in the environment. Other risk factors include chronic exposures, or exposure at critical times, e.g. during fetal development. Since people or ecosystems respond to the total chemical pressure, the combined, aggregated exposure to chemicals is relevant to address. Typically, the dominating sources of exposures are food, water, workplaces, consumer products, air and dust.

Given our lack of knowledge of exposure, the chemical production volume can be used as a proxy for the upper bound exposure. Globally, the production of industrial chemicals increased 57-fold from 1950 to the year 2000, to 400 million tonnes produced yearly ([xxv,xxvi]). In a recent study it was clearly illustrated how '*The diversity and quantity of synthetic chemicals created, distributed, and released into ecosystems have been increasing at rates greatly surpassing those of other drivers of global environmental change*' ([i]). In 2015, Europe alone consumed 350 million tonnes of chemicals, of which 63 % are classified as hazardous to human health and 36 % as hazardous to the environment ([xxvii]). The classification of hazards follows the definitions of the Classification and Labelling of Products (CLP) ([xxviii]), covered under the Registration, Evaluation, Authorisation and Registration of Chemicals Regulation, known as REACH ([xi]). The diversity and quantity of industrial chemicals created, distributed and released into ecosystems via multiple pathways have been increasing at rates greatly surpassing those of other drivers of global environmental change ([xxix]). With the estimated 85 000 chemicals in use, and thousands being registered yearly, it is impossible to make environmental and human risk assessments of chemicals from all sources in all media.

In addition to the known risks, there are issues that are not yet fully understood. Examples include hazards such as endocrine disruption, immunotoxicity or neurotoxicity. An example is the neonicotinoid pesticides affecting the nervous system of bees, identified as one of the stressors causing a rapid decline in the bee populations in Europe ([xxx]). A recent German study shows that both the diversity and the total mass of insects have declined dramatically over the past 27 years ([xxxi]). The animal *in vivo* and the cell *in vitro* studies show decreased fertility due to endocrine disrupters, supported by evidence of a markedly, and possibly irreversible, decrease in fertility in people in the developed countries (e.g. in Europe, the United States and Japan) ([xxxii]). Neurotoxic chemicals have also been associated with higher incidences of behavioural and mental diseases, as well as affecting the IQ (intelligence quotient) ([xxxiii,xxxiv]), which for a society can lead to potentially very costly issues of 'brain drain' ([xxxv]).

Our scientific understanding of what is a safe threshold, or exposure level, for a toxic chemical, has also evolved, and the notion that 'the dose makes the poison' has proved wrong, because, as we now know, that same dose can have different toxicities ([xxxvi]). Examples are the non-linear dose–response relationships, e.g. for bisphenol A ([xxxvii]), or the possibility that any safe thresholds exist during the critical phases in human fetal development, e.g. for lead (Pb) ([xxxiii,xxxiv]). Transformation, degradation or metabolising processes of chemicals are other types of exposures, and hence risks, that are not systematically assessed and monitored. In addition, external factors such as climate change, material recycling rates, urbanisation and ageing may remobilise chemicals from landfills ([xxxviii]) and change pollution pathways and exposure patterns.

In environmental policies, mitigation, adaptation, restoration and avoidance are typical risk governance aspects. Since mitigation, adaptation and restoration address known risks and exposure routes, they are inadequate to manage poorly characterised chemicals (known unknowns) or unknown chemical risks (unknown unknowns).

Mitigation relies on the assumption that all future uses and exposures can be anticipated. While this is already questionable in a linear economy, it may get increasingly difficult in a circular economy. In the circular economy, materials may end up being used for very different purposes than they originally were intended and risk assessed for. Materials that are reused or recycled decades after being produced may contain legacy chemicals, which were either not registered or information may have been lost. Information on the chemical composition of recycled/reused materials can be difficult to trace, and it may in practice be too time consuming or costly to check for all possible chemicals of concern. This underlines the need to focus on the quality of clean materials as a prerequisite for achieving ambitious, quantitative recycling targets.

Restoration and the 'polluter pays' principle assume that pollution, and harm caused by it, is reversible ([xxxix]). Examples of irreversible harm are, however, abundant, such as spills of toxic chemicals in freshwater causing ecosystem collapse, soil pollution and diseases caused by exposure to chemicals during fetal development ([xxiii]). Emissions of persistent and mobile (volatile or highly water-soluble) chemicals may furthermore be impossible to remove from air (e.g. fluorinated gases (F-gases)) and water (e.g. perfluorobutanoic acid (PFBA)). High mobility and persistency are also characteristic for chemicals that may cause planetary boundary risks ([xl]).

Avoiding the use of known chemicals of concern and persistent chemicals is, according to the SAICM ([v]), the most effective governance method to reduce the overall risks from chemicals, both in the short and in the long term. Although avoidance of known or suspected risks does not address the risks from exposure to unknown chemical hazards and exposure routes, it will nevertheless lower the total chemical risk. In the light of the unanticipated uses in a circular economy, remobilisation of hazardous chemicals on account of climate change, as well as the inability to anticipate how future societies will manage and enforce regulation, there is a need for a more precautionary approach to the use of hazardous chemicals ([xxx]). A transition to the use of sustainable, safe-by-design chemicals and products has great innovation potential, which also can support other environmental goals of achieving a low-carbon and circular economy in Europe. This calls for more investments in education, and for research and innovation funding, e.g. as public–private partnerships supported by 1 % of spending across EU research agendas.

Xenia Trier concluded by summarising that risks, being a combination of hazards and exposures, can be decreased by:

- **decreasing the hazards of chemicals:**
    - avoiding the use of substances of very high concern (SVHCs) and persistent chemicals;
    - grouping of chemicals to avoid regrettable substitution;
- **increasing the fraction of sustainable chemicals and products that are safe by design:**
    - apply knowledge of known hazards and persistency in design phase of chemicals/ products;
    - focus on education and R&I across chemicals and product development fields;
- **decreasing the absolute exposure and hence volume of chemicals:**
    - reduce complexity of the diversity and volumes of chemicals;
    - increase ecodesign and non-chemical solutions;
    - use of alternative business models, focusing on selling services rather than products.

In this context, she stressed the importance of making sure that a solution to one environmental problem does not give rise to another, the so-called burden shifting. Recent cases of such regrettable substitution are the chlorofluorocarbons (CFCs), which are ODSs, which were substituted with F-gases, which are potent GHGs. Another case is the persistent, bioaccumulative and toxic (PBT) long-chain perfluorinated substances, which have been replaced with short-chain

Discussions

- It was pointed out that there are also risks that **higher volumes of hazardous substances may be released** as a **consequence of weakened enforcement** of regulations.
- Concern was raised that a **higher volume of chemicals might be needed to achieve the same function**, when substituting with a less toxic chemical alternative.
- A point was raised on **how to deal with the effects of nanomaterials** not covered by the current risk assessment procedures.
- For pesticides we need to consider not just the active substance but also how **additives in pesticide formulations may impact toxicity as well as exposure** routes and uptake for humans and the environment.
- Mitigation works for a lot of chemicals already. At the same time, it is unrealistic to use mitigation to manage and set limits for more than 30 000 chemicals. How well the tool works relies heavily on who has the responsibility to act and pay for it. **Mitigation should be used in combination with other risk governance approaches such as prevention.**

Chemicals, human health and controversies

Presentation by Philippe Grandjean (University of Southern Denmark (SDU))

Philippe Grandjean, professor at the SDU and the Harvard T. H. Chan School of Public Health, took a closer look at the existing scientific evidence of chemical harm to human health, the prevailing mechanisms that support the study of chemicals and health impacts, and how asking for more data may be a deliberate strategy to delay preventive actions to reduce harm.

Professor Grandjean presented data from the World Health Organization (WHO). These data estimate that, out of the global burden of disease, 5-18 % of the disability-adjusted life years (DALY) is attributable to environmental factors ([xli]). This is most likely an underestimate and only the tip of the iceberg, as only factors for which there is clear causality have been taken into account. Our recent global estimate of the impact of major pollutants suggests that the societal cost is at least 10 % of the GDP ([xxii,xlii]).

Other factors causing harm are developmental toxicities, which may lead to lifelong functional deficits, or exposures to mixtures of hazardous chemicals, of which we are currently unaware. As our knowledge expands, the hazardous chemicals usually turn out to be more toxic than first anticipated, illustrated by the case of lead (Pb) and the steady decrease in the safe threshold values of carcinogens from 1946 to 2016 ([xxxiii]).

When the first pieces of evidence of harm emerge, industry's response is often sceptical, demanding further evidence. As evidence mounts, another strategy is to cast doubt, which was a strategy also used to delay action on tobacco or climate change. The response of science is to do more of the same thing and polish the same stone over and over again, as the same few chemicals are studied. A study of 78 major environmental and health journals, covering 120 000 articles, showed that remarkably few chemicals had been studied, and that the top 20 substances were the well-known suspects: heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), ethanol and benzene.

This inertia in science is amplified by funding structures and institutional investments, as well as career progression perspectives prevailing over curiosity. Applications for research funding are typically made within well-established, highly published scientific fields. Institutions are more willing to support studies that make use of existing infrastructure and instruments in order to save costs. In addition, researchers who have devoted a lifetime to study a certain field may be reluctant to admit that other topics of research might be more relevant.

However, from a societal point of view, multidisciplinary research gives a better picture of the risk to get a more comprehensive picture of risks of chemicals to human health. As a result, more exploratory, diverse studies may benefit society by better informing communities on and alleviating any unsubstantiated fears of potential exposure to chemicals in the environment, despite the risk that some studies may fail to provide the answers sought. Furthermore, it takes too long to study all aspects of risk in depth before action is taken. The following questions therefore emerge: How to move forwards? Which criteria should be applied to prioritise research? Who decides which chemicals will allow for a sustainable future? How can the precautionary principle be implemented among a diverse group of stakeholders, including the public, industry, politicians and scientists?

Professor Grandjean offered a few suggestions for consideration. Criteria for environmental health research could put a stronger emphasis on the quality of the study's hypothesis and design in terms of policy relevance, possible impact and innovation potential. He also questioned the way that research is used in risk assessment and where the burden of proof should reside. Research cannot provide all the answers but should rather allow informed decisions on the basis of incomplete evidence. The precautionary principle should be used in such instances to guide decision-makers.

Summary of discussions

- It is true that there is a delayed response, which could be improved. However, we should refrain from generalising on the negative examples. Chemicals have also resulted in many life years gained, e.g. from the use of life-saving drugs. In response to this, it was suggested to go back to basics and **seek to obtain benefits from the use of 'inherently safe chemicals'**.
- The term **'polish the same stone'** was further elaborated on, with the explanation that scientists feel more comfortable dealing with known substances — and that students copy their professors. There was a reflection on how this culture in science could be changed, while recognising that there are no straightforward solutions, given the independent status of academic institutions.
- **Inertia in science** also holds true for **chemical syntheses**: 40 % were discovered before 1900, 40 % between 1900 and World War II, and since then there has been very little work on new chemicals. One suggestion was that Europe could systematically collect case studies on non-toxic chemistry, and steer European research and innovation in this direction.
- The need to move from **evidence-based** to **evidence-informed** approaches was supported. What Europe can do to make that happen was highlighted as a point for future discussion.

Chemicals and ecosystems

Presentation by Dorte Herzke (Norwegian Institute for Air Analysis (NILU))

Dorte Herzke, NILU, spoke about how chemicals spread in the environment and how early warning monitoring and assessments can be designed to detect and prevent contamination. She also addressed the costs of inaction and the factors that eventually lead to regulation.

She started by describing the complexity of the life cycle and fate of chemicals in the Anthropocene, where human resource use is altering the Earth's system. At each step in the life cycle of a chemical – manufacture, use, waste production and management — emissions to the environment can occur. REACH has contributed to reducing the risks of chemicals to the environment, but the impacts can still be severe.

The concept of planetary boundaries provides a lens for understanding chemical impacts on the environment at a global scale ([xliii]). Three boundaries have already been crossed, but the chemical pollution has, so far, not been systematically assessed, as we are not currently able to calculate the scale of the problem. Irreversibility, mobility and toxicity are properties that can be used to characterise chemicals' likelihood of posing planetary boundary risks ([xl,xliv]).

An example of chemical impacts on ecosystems is the use of the anti-inflammatory drug diclofenac, which was administered to treat cows in India. More than 90 % of the vultures feeding on dead livestock died as a result, which led to the collapse of the vulture population. Other pests, such as rats and mice, moved in, and their decaying carcases led to the spread of water-borne disease ([xlv]). Thousands of people died and the estimated costs were estimated at USD 20 billion/year in India ([xlvi]). In 2006, India banned the drug. Also in Europe, drugs used on cattle are putting vulture populations under pressure ([xlvii]).

This is an example of how acute pollution has relatively quickly resulted in regulatory action, because of a direct connection to harm to the human population. Other examples of successful regulations where direct connection to human harm played an important role include CFCs depleting the ozone layer, the regulation of mercury in the Minamata convention ([xlviii]), and acid rain affecting forest vitality and ecosystem health.

The replacement strategies for the chemicals have, however, been of varied success, and there seems to be a common, long timeline to the evolution of legislation, which in many cases takes decades to evolve. PCBs are examples of chemicals that pose planetary boundary risks, and for which regrettable substitution has taken place. More than 200 PCB substances have been replaced by thousands of congeners (isomers) of chlorinated paraffins, which we so far cannot measure accurately. Fluorochemicals is a similar example, where the two main substances (perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS)) have been replaced by diverse, and little measured, alternatives ([xlix]), which also may be toxic ([l]). As an example, in Sweden alone, more than 3 000 poly- and perfluoroalkyl substances (PFASs) are currently in use ([li]).

This raises the question of who judges what risks are acceptable. For PCBs, it took 70 years (1937-1996) from the first health concerns being raised to the 1996 EU directive to eliminate PCBs by 2010. For PFASs, it has taken us 50 years to regulate since the first evidence of bioaccumulation in humans ([lii]). Both PCBs and PFASs are persistent organic pollutants (POPs) that have been found in the atmosphere of the Arctic ([liii]), which is a sink for long-range transboundary pollutants (LRTAPs). PCB levels are getting lower, but PCBs are still there, and are being released from sinks such as older buildings ([liv]). In the last 4 years, cyclic siloxanes have been measured, and they are found in much higher levels than the others — linked to their high production volumes of 30 000 tonnes/year. The lack of application of the precautionary principle has left us with us with legacy contamination. How will we learn the lessons, and when?

This failure to address persistency may partly lie in the standardised tool boxes on POPs in REACH, which largely fail to address, for example, precursors and toxic metabolites, bioaccumulation of persistent surfactants such as PFASs, and late effects and costs of POPs (economic costs are discounted at 2 % per year, despite POPs and their effects increasing over time) ([lv]). These toolboxes therefore need updating.

Early warning monitoring methods should be able to prevent the pollution from spreading irreversibly across the Earth. As such, human biomonitoring might not be the optimal approach, because humans — being top predators — are slow to react, with about a 10-year latency period from the onset of a widespread environmental pollution. Monitoring in faster responding media closer to the (urban) sources, such as air, water and sensitive species, might serve better as an early warning system for environmental pollution. Human biomonitoring can complement this by giving valuable insights about exposure via consumer products and other human-specific exposures.

A better understanding of the use, the volumes emitted, how much is out there, and the life cycle of POPs could also help to improve the fate models. Furthermore, it is important to adapt the fate models to the circular economy paradigm, in order to take the redistribution of contamination in recycled materials into account. The monitoring mechanism would need to be adapted accordingly.

Dorte Herzke concluded by calling for a need to speed up regulation, to replace chemicals with non-toxic chemicals and to adapt the monitoring focus to capture early warning signs of pollution.

Summary of discussions

- Observations were shared that, **in the Stockholm Convention on POPs, chemicals grouping is done to some extent**, e.g. for PFOS and its derivatives.
- When it comes to the legislative curve, there is a **relationship between innovation, profits emerging from innovation and regulation**. Typically, a company that invests money in developing a chemical and taking out a patent will fight against regulation until it has had time to reap the profits.
- Others pointed out the **need to communicate with industry** and to have a constructive dialogue in order to move forward. To be successful, **legislative intervention is best made before the costs are high, or after profits have** been reaped
- **Fate and behaviour of chemicals in the environment can result in metabolites that are hazardous**. Degradation pathways are influenced by environmental conditions. How far should we go in trying to track the degradation? What criteria can we use? Models can be used to understand fate and behaviour in the abiotic environment.
- **How can the regulatory process be speeded up** — taking up to 70 years to regulate, if the process is left to scientists and decision-makers alone, is too long. If we broaden the regulatory process and make it more participatory, can public concern then accelerate regulatory action? A further observation was that we should understand history better, learn from it and act accordingly.

Impacts and costs of chemicals of chemicals on people's wellbeing

Presentation by Michael Depledge (European Centre for Environment and Human Health (ECEHH))

Michael Depledge (ECEHH) presented how chemicals may affect people's health and wellbeing, linked to an individual's resilience, and pointed out that this includes both physical and mental health. WHO's definition of health is: 'Health is a state of complete physical, mental and social wellbeing — not merely the absence of diseases or infirmity' ([lvi]). An open question is whether we can find biomarkers for wellbeing, as we have for many diseases. WHO estimates that mental health will be the main disease by 2050.

One main challenge is that we are currently unsuccessful in measuring human exposure to, and the impacts of, mixtures of anthropogenic chemicals, such as pesticides, fertilisers, industrial chemicals, pharmaceuticals, gases and particulates. It is also unclear who has the responsibility to communicate on chemical safety, with the majority of the public being unaware of chemical risks and therefore unable to protect themselves. Ignorance and fake news affect how we respond to risk, and thereby also how much we are exposed to it.

In this respect, there are both benefits and problems from chemical use. The benefits include, for example, increased life expectancy and increased (more or less distributed) wealth and technological advances, all of which may contribute to happiness, wellbeing and prosperity. The problems caused by chemicals include private or workplace accidents from acute poisoning, insidious effects of chronic poisoning, low-dose effects and impacts of chemicals on mental health. In nature, we also observe chemical imbalances, e.g. in the nitrogen and phosphate cycles. The key question is therefore how we can achieve essential benefits from using chemicals, while minimising the adverse effects.

Michael Depledge went on to talk about how external drivers impact our environment. The process of globalisation changes where and how products are produced and traded; chemical production is increasing and with it diffuse pollution and human exposure. The demography is changing, and life expectancy in the industrial world is increasing, mainly as a result of better medical care rather than as a result of prevention of disease. With age, the use of pharmaceuticals increases, and there is more time to accumulate environmental chemicals in our bodies. Together with decreasing physical resistance, this may lead to higher risk of disease, including mental illness.

There are several examples in the literature of associations of pollutants with mental health, such as heavy metals. Although the changing exposure patterns are difficult to anticipate, we do know that there has been a huge increase in the global chemical production. We also know that the spectrum of chemicals has fundamentally changed from 1960 to 2017 — the question is how that changes our health. We also know that climate change affects the availability of chemicals.

Currently, WHO estimates that 1.7 million children die per year as a result of chemical exposure. Not only is this a tragedy for families and their communities, but it is also very costly to societies. Environment Canada has estimated a variety of annual costs of pollution, being in the order of billions of dollars:

- lost asset values due to pollution — CAD 10.5 billion;
- additional health care cost due to air pollution — CAD 543 billion;
- cost to the economy of protecting the environment from the impacts of pollution — CAD 17.8 billion;
- cost to the federal government of remediating contaminated land and water — CAD 435 billion;
- costs of pollution in terms of out-of-pocket expenses for business and governments — CAD 18.8 billion.

Michael Depledge concluded that we, as society, need to decide what an acceptable future chemical environment is. Public awareness of chemical safety needs to be increased, thereby generating political will. A relevant question would be: do we have a culture for minimising chemical releases, to humans and into the environment? Michael Depledge concluded by calling for more precautions in view of the limited understanding of the way chemical mixtures influence our environment and human health.

Summary of discussions

- The **increased chemical load in elderly people** was recognised; nonetheless, more attention is needs to be paid to **children**, as they **are the most vulnerable**. At the same time, others pointed to the evidence of the **vulnerability of the elderly to chemical exposure**, linked to mental health issues such as dementia and Alzheimer's disease. In the developed world, people now live a **significant part of their lives in their 'old age'**, where staying healthy becomes increasingly important.
- The outcomes of cost–benefit analysis can be strongly influenced by the time period covered. The **costs of long-term impacts typically are not captured in such cost-benefit analyses**, which are biased towards the economic costs of short-term impacts.
- Some **examples exist on** how to evaluate the **costs of impacts on mental health of well-researched substances**, e.g. IQ loss associated with exposure to lead.
- **Tax on pesticides** is an example of a risk management measure to minimise pesticide use.
- **Air pollution** is also a form of **chemical pollution**. The costs of airborne chemical pollution impacts are higher than the costs of exposure to industrial chemicals. It was pointed out that, if the same robust evidence for air pollution was available for other chemicals, then the health costs would be similar.
- A further comment was that the **concern of chemical pollution is high among middle class mothers in relation to their children's exposure**.
- **Early action can prevent long-term costs**, not just for the environment but also for industry. There are always alternatives. What type of chemical alternatives do we need to meet the environmental boundary conditions of the 21st century? How can industry be involved in generating these solutions?

Panel discussion

The panel discussion was initiated by reflections on the presentations by three experts in the field, and was continued with reflections by the presenters. This was followed by an open discussion between all participants. Following this, the panellists were asked to respond in a final round.

Peeter Pärt, Directorate-General (DG) Joint Research Centre (DG JRC), questioned the rationality of people's chemical risk perception in view of other health threats. He considered that the controls on chemicals in our daily lives are high and this generates confidence. On the other hand, the impact of chemicals in early life and their consequences later in life is of concern, and it has for instance been linked to breast cancer in women and testicular cancer in men. The issue is that diseases late in life are difficult to link to the exposure of the pregnant mother 50 years earlier. To Peeter Pärt the main question was therefore to assess whether the exposure today is safe for future generations.

Natacha Cingotti, Health and Environment Alliance (HEAL), pointed out that our society relies heavily on chemicals. At the same time, we have large gaps in our knowledge, particularly of the long-term impacts of chemicals on human health and the environment. From the perspective of environmental health, the overreliance on chemicals fuels other dependencies, e.g. on fossil fuels, which generates climate change and air pollution. These issues are addressed in silos, whereas in fact they are linked. Natacha Cingotti offered some suggestions for moving forwards: we need to inform people more effectively in a balanced way about what they are exposed to and how to protect themselves. If effective tools are made available, people will use them. An example is the German app that tracks chemicals in products. We could also consider which messages are to be channelled to the public and how to do it in a balanced way. Finally, we could bring more of the active stakeholders into the debate. For instance, in the debate on endocrine-disrupting chemicals (EDCs), the insurance industry and the Federation of gynaecologists are speaking out. Medicine is now focusing on individual exposure and health. These actors can contribute usefully to the debate and to finding solutions.

Thomas Backhaus, University of Gothenburg, addressed the inertia in science, where he sees two critical issues: mixtures and planetary boundaries. Mixtures have been studied in the scientific community for some time, and the bottleneck is not a lack of understanding of mixture and combined toxicity. It is rather how to transform the scientific knowledge into regulatory action. Our large regulatory frameworks (REACH, Plant Protection Product Regulation (PPPR), Biocide Regulation) focus on single substances and on single actors, i.e. the chemical producers. This system does not handle chemical mixtures coming from different regulatory areas and sectors. Next, Thomas Backhaus took a critical look at 'planetary boundaries' and questioned how useful the concept is at addressing chemical pollution, which can be of limited useto local hot spots, as in the example of the pesticide contamination of vultures in India. He suggested instead looking at ecosystem impacts and regional and local boundaries. The question would then be how to translate the local/regional data to the global level. Another and related question is how boundaries can be reflected in REACH, which does not address the total toxic pressure, and hence does not address how to translate such a pressure into thresholds for production and/or exposure. The intention and the impact of REACH do not match in this respect.

Following the reflections of the three experts, the presenters were given an opportunity for a quick reply.

Hans Bruyninckx, Executive Director of the EEA, added that both social and natural science should inform the debate. In Europe we have the best knowledge on chemicals and the best institutional structure, as well as the most advanced regulatory framework, so where do we go from here? What will be the next major scientific contributions, and are we doing the right thing, and assessing in the right way? It seems that the toolbox does not really fit into the work we want to get done, with EDCs and with the thousands of chemicals and combinations thereof needing assessment. What may have been good tools in the past, dealing with high acute pollution, may no longer be sufficient to fill in the knowledge gaps or prevent pollution from spreading. Today we have a blanket of chemical pollution everywhere, and there are no longer pristine sites. We need to fill in the knowledge gaps through solid science. We need green and sustainable chemistry to replace hazardous chemicals with new chemicals, and rapidly characterise the hazards of the alternatives.

Philippe Grandjean, SDU, responded, that we first of all need to learn from the past and then to link our overall perspectives across the legislative silos. This connection is currently missing.

Dorte Herzke, NILU, supported the point made by Thomas Backhaus, that we need to define and understand local and regional boundaries first. Most important is, however, that we need to reduce the volumes of chemical production, and the variety, and number, of chemicals used. If we do not, chemical pollution and its complexity will continue to rise.

Summary of discussions

- There is an **increasing need to understand the ecological consequences of chronic, low-level, exposures to mixtures, and for a wider range of pollutants**. More effort should be put into looking at organisms in different environments, including humans, and assessing what happens to their physiology and their behaviour.
- More easily **accessible data on exposure, toxicology and health** are also **needed**. Creating indicators can allow us to establish a baseline to evaluate how pollution targets evolve in the future. The Information Platform for Chemical Monitoring (IPCHeM) and the Human Biomonitoring for EU (HBM4EU) research project will take us some way down that route.
- Similarly, it would be **beneficial to collect what we understand about toxicity** and its link to epidemiology, and to link the chemical events to the resulting biological events. This could increase the knowledge of adverse outcome pathways for whole organisms.
- When assessing individual chemicals, we should also **look at families/groups of chemicals** with similar structural properties and reflect on whether they have similar toxicity. **Big data** approaches might be useful in this regard ([lxiv]). There is a **need to link up our science and regulatory responses** and take a more comprehensive approach.
- Screening of chemicals before they enter the market might be more efficient, since it might be too late to take action by the time chemicals or impacts are found in the environment or in humans. The European Chemicals Agency **(ECHA) would therefore welcome better data and tools to prioritise the 20 000 chemicals**, which they expect to receive registrations for before the 2018 sunset date.
- The scientific community is encouraged to prioritise scientific research to assess new chemicals to improve the data. How can we accelerate the quality of our methods and tools, so we can better assess risks and inform the regulatory process? **Europe needs a toolbox**, not only to **accelerate the transition from science to regulation**, but also to **accelerate science at the design phase of chemicals**.
- **Chemical developments are outpacing society's ability to test and regulate them**. Can grouping of chemicals on the basis of their chemical structure speed up the screenings, knowing that small adjustments to the structure of one chemical can have large effects on its bioactivity?
- **Functional substitution** ([lvii]), such as non-chemical alternatives and reducing chemical use **need more consideration**. Part of the **problem is the dynamics of an innovation system that promotes the existing trajectory**. Industry can patent new chemicals for profit. More knowledge is needed about the dynamics of this system and how this trajectory can be shifted. How can Europe promote greater diversity in innovation pathways ([lviii])?
- There is a need to recognise both the benefits and the detrimental effects of chemicals — but **how can the balance be struck between innovation in chemicals with potential risks**?
- The EEA reports ***Late lessons from early warnings*** highlights the need to act earlier. How can this knowledge be **translated into different actions?**

Final feedback from panellists

- **Natasha Cingotti**: The discussions revolved around two levels — how to translate science into knowledge and how to take action. Possible roads that have been mentioned are promotion of alternatives and tools and methods to build knowledge (e.g. ToxBox). Europe could also implement existing systems more strictly, for instance by rejecting ECHA registration dossiers if the data are incomplete. However, there is also the need for a more fundamental debate on the effectiveness of chemical management systems and of society's reliance on chemicals.
- **Thomas Backhaus**: More multi-disciplinary discussions would help to solve the problems from all sides of the spectrum and to put knowledge into action. Many modern elements of science are not embedded in regulations. Europe urgently needs a shift from single-substance evaluation towards an evaluation of chemical groups. Some chemicals are regulated under multiple different frameworks, REACH, PPPR, pharmaceuticals — but which legislation takes precedence? Finally, regrettable substitutions must be avoided as far as practicable. The scientific community is willing to help, but there is a need for better transparency of information and accessibility to, for example, production data and exposure data, which are not public. If Europe can optimise the sharing of data, the scientific community could be in a better position to support risk assessment.
- **Peeter Pärt**: Chemicals have brought a wide range of benefits to Europe's citizens, such as pharmaceuticals to improve health. Chemicals do not pose a daily health threat. What is, however, not known is what will happen with future generations because of low-dose effects and impacts on fetal development. Progress by regulators in putting some order into the regulation of chemicals should be acknowledged.
- **Michael Depledge**: Yes, chemicals have contributed to life expectancy and to food production. But what about wellbeing? Chemical use has alleviated poverty and provided other benefits, but these have not always been evenly distributed.
- **Phillip Grandjean**: There has been a vicious circle of regrettable substitution, e.g. for the PFASs. The overview will not come from science. Science has a tradition of hedging when interpreting results. Can the regulators convene and form a consensus on how to extrapolate scientific evidence into risk and communicate this to the public and regulatory approaches?
- **Dorte Herzke**: More attention is needed on cost–benefit analysis, as well as to learn from history where decision-makers did manage to act in time, and how this benefited society.
- **Xenia Trier**: To get out of the futile cycle of regrettable substitution, there is a need to go upstream, as ECHA mentioned. More efforts are needed to screen properties such as persistence and mobility in the design phase. Education and training of chemists and engineers could be improved, so that existing knowledge can already be applied in the design phase of products and processes. Future policy efforts should encourage non-chemical solutions and the development of chemicals that are safe by design (i.e. non-toxic as well as compatible with the circular and the low-carbon economies), while delivering the desired function.
- **Hans Bruyninckx**: Europe now has a vast knowledge base on chemicals as well as an increased knowledge regarding the impacts of chemicals. How do we turn this knowledge we have into an operational evidence base for risk management? Can 'big data' be incorporated? Should more efforts go into computational biology? What about the exposome? What can bio-based chemistry contribute? There is a clear need for much more integrative science, through making best possible use of available innovation drivers, such as Horizon 2020 research funds.

Session 2: How to respond? Strategic options

Policy synergies and opportunities

Presentation by Bjørn Hansen (DG Environment)

Bjørn Hansen, Head of Unit B2, DG Environment, gave a presentation on chemicals for a sustainable future, policy synergies and opportunities.

The 7th EAP presents a long-term vision of living well within the limits of the planet, where the current baseline protection level for chemicals of natural or manufactured origins is provided by the EU chemical policy acquis. Environmental policy kicks in when we have unintentional releases of chemicals, which chemical policies did not manage to control.

The environmental legislation is based on the three principles in the Lisbon Treaty (precaution, polluter pays, rectification at source) and aims to achieve a high level of protection. Themes include **waste** (implementing the waste hierarchy), **water** (including water quality) and **air** (including industrial emissions and product controls). Chemicals policy is also based on the internal market and is designed to promote competitiveness and innovation and non-animal testing. Baseline protection is provided by REACH (and its refit evaluation), CLP implementation, better regulation, the Commission's Regulatory Fitness and Performance (REFIT) evaluation of REACH, and the circular economy package. With regards to the circular economy, the interface between the legislative domains of the REACH phase (production and use phase of substances, mixtures and articles) and the waste phase is critical ([lix],[lx]).

The chemicals acquis will continue to evolve, in line with public concern. Meanwhile, the 7th EAP identifies areas that need additional attention, including nanomaterials, endocrine disrupters substances in articles, unintentional mixtures and extremely persistent chemicals. Endocrine disrupters and nanomaterials will be addressed from a regulatory perspective, whereas REACH will address EDCs, and the annexes will be amended to address nanomaterials. Data are scarce in these areas.

The big challenges are substances in articles (i.e. products) and mixtures. The 7th EAP calls for the minimisation of exposure to chemicals, recognising multiple exposures, and of the lack of tools to assess the risks. How can we address this? Do we all reduce chemical use by 10 %? Do we increase the risk factors?

NOTES identifies those areas that need additional attention, and it is anticipated that it will be made public by 2018. It will address the following topics:

a) substitution, including grouping of chemicals and measures to support substitution;

b) chemicals in products and non-toxic material cycles;

c) the improved protection of children and vulnerable groups from harmful exposure to chemicals;

d) a sub-strategy for extremely persistent chemicals;

e) policy means, innovation and competitiveness;

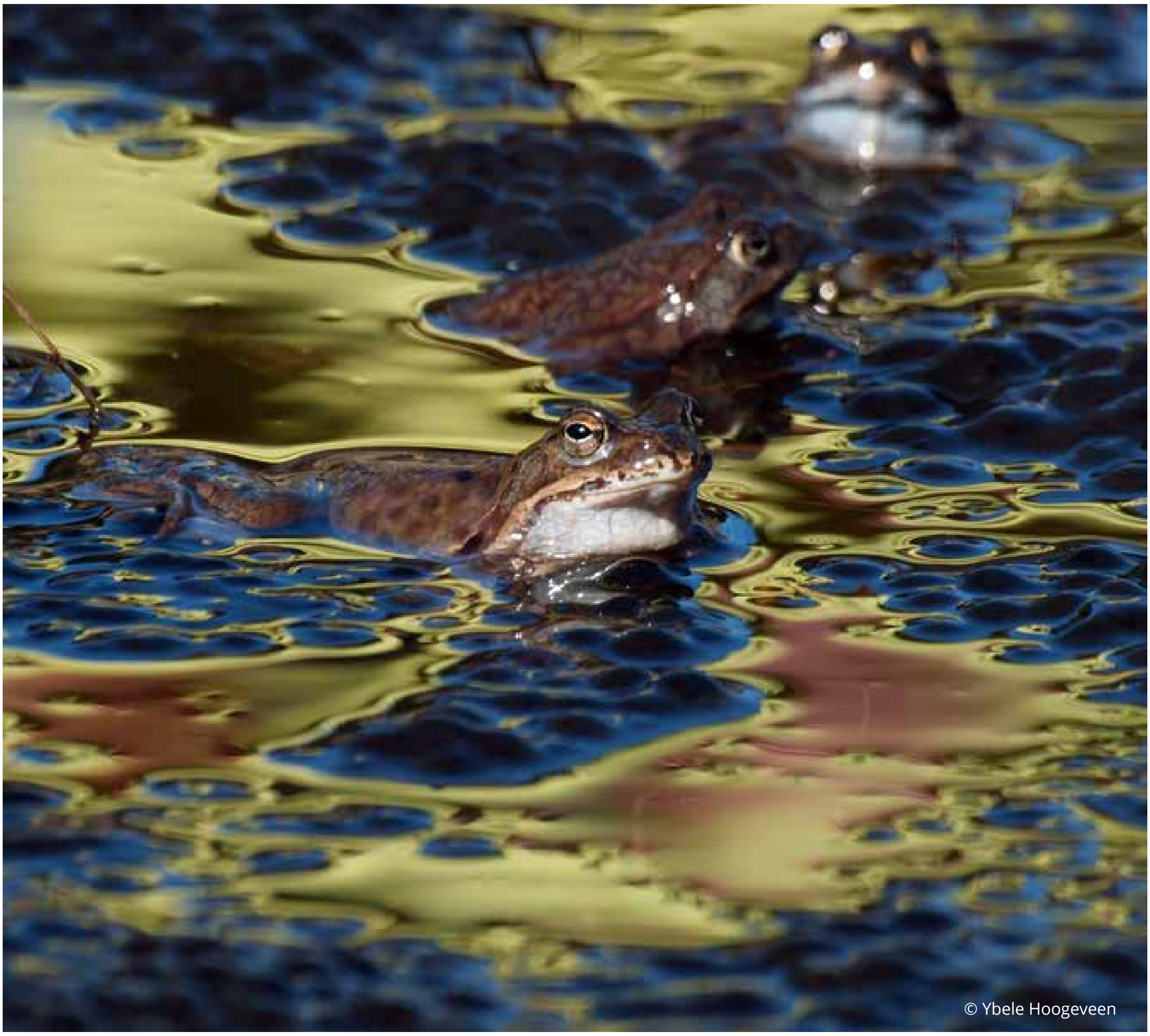
f) a green chemicals programme;

g) a joint early warning system for approaching chemical threats to health and the environment.

Bjørn Hansen went on to describe some of the challenges that we face in achieving the goals of the 7th EAP. The first set of challenges relate to the direction of our society. Economic growth is still a strong driver for our actions, which, in a linear economy, creates waste. Meanwhile, the complexity of our products is increasing, as is the development of composite materials. This makes it harder to separate and recycle materials. We are also seeing an increase in the numbers and production volumes of chemicals. Going circular will put demands on these areas and will set limits for development in the directions that are incompatible with circularity.

Next he went on to address the challenge of how to integrate policies on various types of chemicals, and across policy silos. He suggested that a key to better

integrated environmental policies might be to look at the world from an upstream **chemicals perspective**, in contrast to a product and articles perspective; the chemical impact on humans or ecosystems is insensitive to how many sources the chemicals come from, or which legislations it is covered by. What matters is the total impact. In terms of governance, the principles to follow to minimise the risks from chemicals resemble the first two steps of the waste hierarchy (reduce, reuse), which for chemicals is to avoid and minimise the use of chemicals.
It can be questioned whether our current legislative tools are sufficient to fully support the goals of circularity and sustainability. An example is risk assessment, where the current impact assessment methodology is biased towards short-term profits, allowing chemicals on to the market that may have severe long-term impacts and associated costs.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Chemicals and risk: improving assessment of chemicals

Presentation by Marlene Ågerstrand (Stockholm University)

Marlene Ågerstrand spoke about chemicals and risks, and questioned whether more data will provide better risk assessments, in comparison to focusing on fewer aspects linked to the value judgement of policy. She started out by posing three critical questions:

1. Are our assessment methodologies helping us arrive at science-based conclusions?

2. Are we using our resources effectively?

3. Are we assessing the right aspects?

On the first question, Marlene pointed out that experts tend to disagree when it comes to the risks from chemicals. Recent examples are bisphenol A, the herbicides atrazine and glyphosate, and brominated flame retardants (BFRs). She concluded that our disagreements and problems cannot be solved by science. Rather, they can be solved only by policy and by balancing different values against each other. Ambiguity in science arises from differences in data availability and data selection, interpretation and evaluation. Often there is also a conflict between the use of standardised (good laboratory practice) vs non-standard data. This may influence the study design, in terms of both which parameters and how many parameters the studies include, and also how statistically significant a study will be. Transparency can help to address this.

Systematic review methodologies, such as the Cochrane review method can be used to risk assess chemicals; this method emphasises reproducibility, transparency and making use of all the available studies. Marlene Ågerstrand went on to describe SYRINA, which is a framework for the systematic review and integrated assessment of endocrine disruption, as an example to illustrate how systematic assessments can be done in practice ([lxi]). The idea is that the inclusion of more information, from standardised and non-standardised studies, will decrease the overall uncertainty and give a higher quality assessment.

However, making very extensive risk assessments can be very complex and resource intense, and what is even more troublesome is that minor details sway the conclusions, according to a study by the Swedish Chemicals Agency KEMI. The outcome of the risk assessments therefore become less predictable, and comparability across products is difficult. This is obviously not an ideal situation, particularly not for companies applying for an authorisation.

It raises the second and third questions: are we using our resources effectively, and are we assessing the right aspects? To find this out, KEMI compared the full assessment with a simplified one, focusing on fewer aspects of high relevance for biodiversity and leakage to groundwater. These essential aspects include persistence, ecotoxicity and the volumes of chemicals that are used. What it found was that the full risk assessment and the simplified assessments arrived at similar conclusions. More data do therefore not necessarily give clearer answers to policy questions, but focusing on the more important aspect can make you do the job faster, and thereby free up resources for other activities.

Another relevant aspect that so far has not been dealt with in the KEMI strategy, is the **mobility** of chemicals. Current assessment criteria focus on chemicals that are persistent, bioaccumulative and toxic (PBT/vPvB), which reflect the 'old' problems they were designed to deal with (such as DDT and PCBs, which accumulate in fatty tissues). These criteria cannot address the problems of managing chemicals that, in addition to being persistent and toxic, are very mobile (i.e. water soluble or volatile), the so-called PMT (persistent, mobile and toxic) or vPvM (very persistent and very mobile) substances. The mobility of PMT substances makes them extremely difficult to remove from water or air emissions, or even to remediate in contaminated soil or drinking water. PFASs with short chain lengths (e.g. ≤ C4), are examples of regrettable PMT substances, which have been introduced as replacement for the longer-chain PFASs to avoid bioaccumulability. Since M is mobility, it is linked to the solubility in water or to the boiling point in air. These data are already now available in REACH registration dossiers, and could be used if the PMT or the vPvM criteria was introduced.

Marlene Ågerstrand urged both researchers and policymakers to take joint action. The researchers could design studies to find the relevant regulatory information, and take the time to interact with policymakers. This would increase the regulatory usefulness of peer-reviewed data. Meanwhile researchers should train the next generation of scientists in the skills used in regulatory risk assessments. Interaction with policymakers has significant potential. Regulators can also play their part to improve the methodologies, be more flexible in accepting a range of knowledge from scientists and more generally support the field of science-policy research.

She concluded with the following take-home messages:

- More data do not always solve the problem.
- We can use data more effectively by focusing on the most critical parameters (PBT, PMT, ecotoxicity). This will free up resources to analyse more of the chemicals out there.

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Chemicals in the circular economy

Presentation by Alice Bernard (Client Earth)

Alice Bernard (Client Earth) presented on chemicals in a circular economy, and she illustrated the dilemmas and difficulties of accessing information on chemicals of concern with an example of a mattress containing the BFR called hexabromocyclododecane (HBCDD), which was being recycled as insulation for a car.

The 7th EAP mentions the objectives of the circular economy and the non-toxic environment on a par, and they should therefore be pursued in parallel. One main challenge is, however, that it is not easy to amend our chemicals regulation to take into account new knowledge on chemical risks. The delays in action to restrict the use of toxic substances imply that more hazardous substances enter the material flows.

Part of the regulatory problem is that chemicals are addressed in blocks of legislation that are designed for a linear economy and by different principles:

- Chemicals (substances and mixtures) are regulated by e.g. REACH/CLP, and POPs by the United Nations Environment Plan's Stockholm convention.
- Products/articles (e.g. toys, cars and cosmetics) are regulated by thematic legislation (ecodesign, general product safety directive).
- Waste is regulated by waste legislation.

What is needed is to take a more holistic approach. To illustrate the interactions of these regulations and how they work — or not — in practice, e.g. in the transfer of information on chemicals through the life cycle of a product, Client Earth did a case study on HBCDD in the ticking of a mattress. HBCDD is a BFR and is listed by ECHA as a SVHC, which is why it is on the REACH authorisation list. This means that uses of HBCDD after 2015 require authorisation. Meanwhile, HBCDD is restricted under the Stockholm Convention.

At the time that HBCDD was added to the ticking of the mattress it was not on the list of SVHCs, and therefore went through REACH registration without a requirement to ensure information on recycling. Information on the presence and quantities of HBCDD does not therefore follow the mattress and the recycler will not be able to know about the HBCDD unless they test for it. However, as an article, here the textile in the mattress ends up as waste. There are currently no 'end-of-(article)-life' criteria and hence no requirements to test the textile. As a consequence, the recycler will not have access to information on HBCDD for the new use.

Furthermore, at the point HBCDD was added to the mattress, the particular use was evaluated; for instance, it can be assumed that the mattress will never be warmer than room temperature, say maximum 40 °C. Volatilisation of HBCDD would therefore be deemed of little concern. On recycling into the doors of a car, the textile might, however, be exposed to much higher temperatures, for instance if the car is left in the sun or if a local heater is put on. This is an unanticipated use of the textile, and the assumption that the volatilisation of HBCDD is negligible might no longer hold true. In order to ensure a high level of protection for the environment, adequate information needs to be available throughout the life cycle of a material. Current legislation and management practices do not sufficiently warrant that.

Alice concluded by stressing three points, which she sees as key to achieving a high level of protection for the health of humans and the environment, in support of both a non-toxic environment and a clean circular economy:

- Ensure information on chemicals throughout the entire life cycle.
- No double standards for virgin and recycled materials — or a toxic circular economy will be created.
- Avoid/limit the use of hazardous substances in products.

Chemicals for a non-toxic environment

Presentation by Walter Leitner (RWTH Aachen University)

Walter Leitner, RWTH Aachen University, presented on chemicals for a non-toxic environment, and started by taking a look at the petrochemical value chain, which is at the heart of this age of petro-chemistry. It is a highly interlinked value chain leading from petroleum as the currently most important carbon resource to the production of some 100 000 chemicals in a broad range of sectors. Whereas 90 % of the fossil fuels go to energy, only 10 % go to produce chemicals and products. In addition to the petrochemical value chain, there are other resource streams such as minerals and wood. The desire for new and improved products creates a drive for what can be new sustainable synthetic pathways and processes. A challenge for sustainability is whether we can identify alternative feedstocks for chemical production and reduce our dependency on the petrochemical industry. This will require that we address the design phase of chemicals.

Green chemistry is about the design of chemicals to achieve sustainability, and it follows the 12 principles suggested by Paul Anastas and John Warner in 1998 ([lxii]). Most of today's regulations focus on reducing risk by reducing exposure. If we reduce the inherent hazards of a molecule and/or its production we will, however, also reduce the risk. This shift from an 'end-of-pipe' regulation towards more 'upstream' and 'benign-by-design' regulations is evident in the United States. Nevertheless, we cannot always be sure to avoid risk, as there will always be unknown unknowns. An example is thalidomide, a drug prescribed against nausea during pregnancy, which was found to have no acute toxicity according to studies done at the time. What was unknown, was that the two 'mirror images' (stereochemistries) of the drug have different toxicities, whereby one causes teratogenic effects and leads to malformation of the limbs of fetuses. This example also disproved the paradigm that 'only the dose makes the poison', since the effect is not dependent only on the dose. Rather, the critical dose causing an effect may vary at different times in life and for different people. Exposure to a 'poison' during pregnancy is an example of a so-called critical time of exposure, where low doses may cause severe and long-term harm later in life.

Therefore, in the design phase, rather than focusing on the molecule, it provides us with more degrees of freedom if we focus on the function we aim for. The reason is that the molecular structure of the chemical relates not only to the function, but also to the environmental and health impacts, such as carbon footprint, toxicity, eco-toxicity and persistency. The function on the other hand is a broader term, which relates not only to the chemical structure, but also to the product design. Both of these objectives need to be addressed in the multiple stages of chemical development and production.

Walter Leitner provided the example of a polyurethane polymer, in which the goal of lowering the CO_2 footprint was achieved — by adding CO_2 to the polymer! This reduced the use of the fossil fuel-based polyurethane materials and made the overall product lighter, requiring less energy to transport. Not only did this lower the product's overall CO_2 emissions, but the toxic and other impacts of the product were also lowered. Another example is the quest for green solvents, in which at some point the pharmaceutical industry sat down and asked each other if they faced similar problems with solvent toxicity and management — which they did. They then made a list of unwanted solvents and asked scientists to create new innovations, which could serve the functions previously delivered by the phased-out solvents.

A key message is that to succeed with your design, you **need a clear set of design criteria** for which function or service your design will deliver. You also need to understand the mechanisms of toxicity you would like to avoid, or at least which families or groups of chemicals do not possess toxicities. These are just a few examples, since there are many other important points to address with regard to production, infrastructure, supply and cost, to mention a few.

Walter Leitner therefore asked the crucial question, whether a 'non-toxic environment' really can be a target from which design criteria can be derived. To clarify the design criteria, it is relevant to ask what the purpose of a non-toxic environment is. What is the ambition of creating this other 'place', and in what ways is it better, rather than less bad? In addition, we need to think about the implementation of whichever tools and regulations we could put in place and how to embrace all stakeholders, so that they will carry the mission through to achieve a non-toxic environment.

Panel discussion

The panel discussion started off with reflections on the presentations by three experts in the field. It was continued with reflections by the presenters, and led to an open discussion between all participants. Following this, the panellists were asked to respond in a final round.

Per Mickwicz asked if ECHA and DG GROW (Internal Market, Industry, Entrepreneurship and Small and Medium-sized Enterprises) give the right incentives, and asked the speakers to reflect on the REFIT priorities: **mixtures, grouping and chemicals in products**.

Michel Philippe, L'Oréal, called for a strong focus on ecodesign, from the very beginning of the product development, as when the product is developed it is often too late. This involves assessing the environmental performance of the raw materials, such as the bio-based products, and the production process, as well as working closely with suppliers. This leads to gradual improvements, which also are passed down the supply chain. He noted that the collection of all the data is a huge challenge. He suggested developing methods using the existing tools, which could be more specific the more specific the targets are ([lxiii,lxiv,lxv]).

Jack de Bruijn, ECHA, highlighted three main points: we have come a long way since REACH was introduced 10 years ago. Nevertheless, it is essential that we have better knowledge on chemicals, particularly in the long term. With 10 000-20 000 substances awaiting assessment, we would like to avoid extensive animal testing, by using *in silico* methods such as QSAR and *in vitro* testing for toxicity. ECHA would highly appreciate having better information on how to prioritise chemicals. There is also a lot to be done with regard to the tracking of hazardous substances in articles, particularly in relation to the circular economy, and although the app tracking SVHCs in articles is a good initiative to create awareness, about 99 % of the products are not in the products database. On the positive side, there is a greater interest in sustainability issues from front-running businesses. ECHA can certainly help by sharing the knowledge it has on chemicals. The main question is, however, which alternative chemicals to replace the hazardous chemicals with. Both existing chemicals and the alternatives need to be assessed effectively, and it is necessary to understand the technical function of the chemicals. In his opinion, the tools to make things work exist. He stressed that the link to innovation is crucial and suggested that, if 1 % of the funding in all the EU research programmes were linked to chemicals, it could drive a lot more innovation in the right direction.

Otto Linher, DG GROW, made the point that chemicals, such as pharmaceuticals and pesticides, have diminished poverty compared with the past. He also made the observation that the REFIT concluded several things in line with the circular economy and NOTES: mixture toxicity is not yet properly dealt with. Grouping could help to avoid regrettable substitutions, but there are some challenges to implementing it within the existing legal frameworks. Substances in articles need to be better labelled and communicated to consumers, possibly by digital tools, while respecting confidentiality. In his opinion, legislation is the most direct way to trigger innovation, and he agreed with Jack de Bruijn that this can happen through research programmes.

Marlene Ågerstrand, University of Stockholm, agreed with the REFIT priorities of focusing on **mixtures, grouping and chemicals in products**.

Alice Bernard, Client Earth, made the comment that, while tracking of chemicals in products is desirable, business's claims of confidentiality block the availability of data on chemicals in products.

Bjørn Hansen, DG ENV, commented on the REFIT priorities by noting that REACH and CLP do not hinder the grouping of chemicals. Unintentional mixtures are recognised as a problem to be addressed. With regard to how to address substances in products, we need to provide 'carrots' for industry. Since they have to invest upfront to get a profit later on, they need a legal certainty, which only regulation can provide.

Walter Leitner, RWTH Aachen University, highlighted two key aspects of how to support a transition to green chemistry: education of chemists and engineers, and more attention on the infrastructure to support small and medium-sized enterprises and companies wanting to explore safe-by-design options. Investments into new processes are also needed. Finally, he pointed out that the structure of the petrochemical industry poses a high barrier for young entrepreneurs to start-up companies, calling for mechanisms to support such initiatives.

Summary of discussions

- It was questioned whether society really needs so many different chemicals, for instance thousands of colours. What are the essential needs? To address the delays in policy cycles, education cycles and information cycles, Europe needs to move ahead of the existing institutional and intellectual frameworks. Not just more research, but more innovation in safe products.
- In transitioning to a circular economy, Europe should reflect on the necessity of chemicals, and make materials that can be destroyed. If a chemical obstructs clean material cycles and requires destruction of the material, it should be considered whether the chemical really is essential. Europe also needs to set standards for materials and define the boundaries for what is a material. A point was raised about how the global chemical industry would be taken into account when setting standards. DG GROW cautioned against restricting the number of chemicals on the market in order to promote a circular economy.
- Europe has seen substantial improvements in the reduction of pollution, which shows that the progressive EU agenda works. Together with SAICM, there is every chance to succeed further.
- EU legislation is seen as a positive example of how to regulate chemicals outside the EU. As the non-EU countries are catching up with the EU, their populations are demanding higher standards. The progressive EU agenda is very useful in pushing global actions on chemicals.
- Research needs to look beyond the legacy chemicals, such as lead, to address emerging issues such as fluorinated substances and the new PMT criteria.
- When implementing policies to achieve a non-toxic environment, the EEA could develop indicators and effect measures to determine whether we are on the right track. It will be important to link the chemical indicators further to the Sustainable Development Goals (SDGs) indicators process.
- Legislation does not address the impacts of chemicals produced globally and used in Europe. Internationally, the legislative frameworks are developing and this will increase scrutiny of chemicals in products that are manufactured outside the EU. EU chemical producers also need to improve their practice in channelling chemical safety data sheets to manufacturers who are using their chemicals outside the EU.
- Europe has a unique opportunity to design materials and chemicals for circularity. There are synergies with innovation policy, which can be used to stimulate research and innovation. There is a need to communicate more effectively with designers and understand what motivates them, and introduce a safe-by-design approach when designing products, with the principles of green chemistry as a priority.

Final feedback from panellists

- **Marlene Ågerstrand** was hopeful that the time was ripe to make progress, given the actors and consensus in the room.
- **Walter Leitner** reminded the participants that Europe is in an excellent position, since it has creativity, tools and an industrial infrastructure. If the regulatory framework includes incentive mechanisms to put innovators in the right direction, there is a good chance to innovate chemicals for a sustainable future.
- **Alice Bernard** said that how legislation is put into action as well as enforcement of the rules are critical. In the future, it has to be advantageous for companies to comply with rules.
- **Bjørn Hansen** was of the opinion that bridging legislation and making it more coherent across legislative silos is the number one priority. In order to merge legislation, we must look at the world from a chemicals angle and see pollutants as chemicals. As a starting point, the principles of the waste hierarchy of reduce–reuse could be applied to chemicals.
- **Jack de Bruijn** pointed out that we have the tools to make things work, but that it is critical that we link them to innovation. Allocating 1 % of Europe's R&I budget to chemicals could drive innovation in the right direction.
- **Michel Philippe** said that it is essential to promote ecodesign and green chemistry, using bio-based raw materials. In doing so we can use existing tools to ensure environmental sustainability.
- **Otto Linher** urged the EEA to identify the issues, to make them clear and to communicate clearly about them. He also agreed that innovation is a very important aspect, and proposed that we focus on how to shape the carrot, to support the transition to a society based on sustainable chemicals.

Concluding remarks

Greet Schoeters, EEA Scientific Committee, provided some closing remarks:

The overall conclusion was an optimistic one: as we want to live well on our planet, chemicals will be part of our future. The pressures from chemicals on vulnerable ecosystems and humans are increasing, as a result of demography, urbanisation, resource scarcity and climate change, but it is possible for society to decrease these pressures.

There are many challenges and risks but also opportunities for innovation in science, in product design and in assessment strategies. Shifting from the conflict model between stakeholders to new ways of collaborating between industry, scientists and regulators, building on trust and transparency, will be needed for this transition.

The use of and associated exposure to chemicals will increase over the next decade. The production volumes will increase, the number of chemicals will increase, and there will be more diversity (e.g. new nanomaterials, bio-based chemicals, pharmaceuticals). It was shown that 40 % of the substances detected in Arctic air were unknown chemicals. As part of the strategy towards a circular economy, the life time of chemicals will be prolonged.

Climate change, resource scarcity, global trade, demography and urbanisation will increase human exposure to chemicals and put pressure on vulnerable groups and ecosystems. This implies that society will continue to have to deal with chemicals in the environment, and will need to adapt to new exposure scenarios. As we will have the benefits of these chemicals, we are also challenged to turn this into opportunities for innovative research and regulations. This will require new partnerships between chemists, natural scientists, social scientists and regulators.

There could be strong synergies between reducing the effects of hazardous chemicals, as aimed for in NOTES, and the goals set for the circular, bio-based and low-carbon economies. Chemicals are connectors, but a new systemic approach is needed for chemicals, which should be seen in a broad context. Chemicals need to be assessed and addressed by policies along their whole life cycle of production, use, transport, export, recycling or waste. Recycling of products and materials implies that the life time of chemicals can be almost infinite, as was demonstrated by the life cycle of HCBDD in mattresses.

More and more chemicals will be bio-based instead of fossil fuel based, which is why they also link to the circular economy and to energy use. Currently there are gaps in the regulations to trace the fate of chemicals in the production and consumption systems. There is lack of transparency and lack of procedures to ensure safe circulation. It was questioned whether we have the right indicators, assessment tools and whether the assessment strategies for circularity and for sustainability are appropriate and include chemicals. Do we know the planetary boundaries for chemicals?

How can science help? Science has shown some inertia regarding studies on new chemicals and their effects. There is an oversupply of studies on old chemicals such as heavy metals and already banned POPs. There may be various reasons for this, such as discussions on uncertainty, expensive analytical equipment, ease of publishing, and funding structures linked to established academic careers. Altered monitoring strategies of fast-responding species, such as air, water and biota, can provide early warnings of pollution. Chemicals that are mobile, persistent and have high eco-toxicity may be particularly important as inputs for risk assessments.

The scientific community should also be challenged to adopt more innovative scientific approaches and focus on the issues, such as long-term effects of chemicals at the population level, irreversible effects that persist over the generations, inequality of people's exposure related to their socio-economic status and exposures to mixtures. We need improved monitoring tools for low exposure levels and for aggregated exposures.

The HBM4EU project in which the EEA participates is a step forwards in this direction. We need to apply new tools to study toxicity. The concept of identifying 'adverse outcome pathways' on which chemicals and their combinations may act is such a new approach, as is the use of systematic reviews, read across, in silico and in vitro screening, such as used in the US TOX 21/TOXCAST programmes.

Many data are already available and the database will grow rapidly; however, these data are not always openly accessible and are not readily captured by regulators who are still working with the old paradigms and use the results of animal tests that are more than 50 years old. The use of big data could help to guide the innovation and design of benign chemicals by understanding which branches of the 'chemical tree' contain groups of toxic chemicals and which contain benign chemicals.

Adaptation governance tools, which can provide protection in the short term, were discussed. Examples included avoiding and minimising exposures particularly to the chemicals of concern, such as persistent chemicals, SVHCs, PMT or vPvM chemicals, or PBT or vPvB chemicals.

Avoiding the use of chemicals of concern was identified as one of the most effective long-term governance tools. Chemical safety should already be addressed in the very early development phases of product design and selection or development of new materials, where the safest substances should be selected. Already existing tools and scientific knowledge on chemical safety can be put into action at this early stage. By focusing on the function and service a material or product should deliver, rather than on the molecule, opportunities would be created for non-chemical solutions.

Education, training and raising awareness of product designers is a prerequisite, as is the availability and acceptance of rapid screening tools for selecting the safest substances. Ecodesign, green chemistry and bio-based ingredients should comply with this approach, and incentives are needed for companies to invest in safe design. We need to better understand how the chemical infrastructure works in order to assist the necessary transition to provide chemicals for a sustainable future.

What should our chemical future look like? To be able to use innovative chemicals in products and materials safely and to circulate them through the economy in a safe way cannot be accomplished by natural scientists on their own. We need to move away from the conflict model towards a new model of collaboration, transparency and trust between industry, scientists and regulators. Accessible information should be made available to the public so that they are well informed to participate in the debate and are able to protect themselves.

Stakeholders should be convened to develop a common vision on a desirable future in which we use green and sustainable chemistry to provide essential services. The EEA can take up the important role of building knowledge on the systemic dimensions of chemicals and help by bringing the actors together in dialogue to develop a common vision.

Hans Bruyninckx, EEA Executive Director, closed the meeting by thanking all participants. To address the question of what a sustainable future should be, we need to understand what frames, visions and policies are in place to support a transition to a sustainable future. Incremental changes in reducing pollution will not get us to the sustainable future. We need a profound transition, for which the 7th EAP provides a vision. Regulations cannot provide visions, but we need a persuasive narrative to get society and people motivated to make change happen.
The chemical sectors play a crucial role in shaping a sustainable future for 10 billion people on the planet, and this is a big opportunity for the chemicals sector. The EEA wants to be a partner in this collective effort.

Annex 1: Seminar agenda

Time: Wednesday 17 May 2017, 08:30-17:00

Place: EEA, Kongens Nytorv 6, Copenhagen, Denmark

8:30-9:00	Registration and coffee
9:00-9:15	**Welcome by Chairs, meeting objectives** Per Mickwitz, EEA Scientific Committee Hans Bruyninckx, Executive Director, EEA
Morning session: What is at stake? Key scientific insights	
9:15-11:00	• Xenia Trier (EEA): Chemicals and the environment in Europe • Philippe Grandjean (EEA Scientific Committee): Chemicals, human health and controversies • Dorte Herzke (NILU): Chemicals and ecosystems • Michael Depledge (ECEHH): Impacts and costs of chemicals on human wellbeing
11:00-11:30	Coffee break
11:30-12:30	**Panel discussion**: speakers and panel members: Peeter Pärt (DG JRC), Natacha Cingotti (HEAL), Thomas Backhaus (University of Gothenborg)
12:30-13:30	Lunch
Afternoon session: how to respond? Strategic options	
13:30-15:15	• Bjørn Hansen (DG ENV): Policy synergies and opportunities • Marlene Ågerstrand (ACES, Stockholm University): Chemicals and risk assessment • Alice Bernard (Client Earth): Chemicals in a circular economy • Walter Leitner (RWTH Aachen University): Chemicals for a non-toxic environment
15:15-15:45	Coffee break
15:45-16:45	**Panel discussion**: Speakers and panel members: Michel Philippe (L'Oréal), Jack de Bruijn (ECHA), Otto Linher (DG GROW)
16:45-17:00	Closing remarks by Greet Schoeters, Per Mickwitz and Hans Bruyninckx
18:00	Dinner

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