Beneficiary contributions of the concept of Sustainable Chemistry to the Strategic Approach to International Chemicals Management beyond 2020

Policy paper as stimulus for the lunch dialogue during the first intersessional meeting in Brasilia

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1 Summary and conclusions

Sustainable Chemistry is a concept which contributes to achieving numerous goals of the 2030 Agenda for Sustainable Development (SDGs). It is based, amongst others, on the principles of “green chemistry” and has interfaces with important topics such as resource conservation, waste management, occupational safety, employee and consumer health, and nutrition. Sustainable chemistry combines ecologically viable solutions with economic success under consideration of societal and social demands.

The important mission of advancing sustainable chemistry stems from the 2030 Agenda for Sustainable Development adopted in September 2015. In goals defined therein (SDGs), the chemical industry and the products it manufactures play an important role. A chemicals policy with a prime focus on chemical safety is not enough to achieve these goals. It is rather more the case that a holistic approach is needed, which integrates the ecological, economic and social/societal aspects in the life-cycle of chemicals into the decision-making process regarding their manufacture and use.

“Sustainable chemistry is a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services”, states the OECD[1]. The concept’s aim, amongst others, is “to maximise resource efficiency through activities such as energy and non-renewable resource conservation, risk minimisation, pollution prevention, minimisation of waste at all stages of a product life-cycle…”. That is why sustainable chemistry presupposes the prudent handling of chemicals and the reduction of waste (sound management of chemicals and waste – SMCW). The OECD definition however falls short of other relevant aspects of sustainability, for example full life-cycle assessment, conservation of resources, promotion of reuse and recycling, application of corporate social responsibility (CSR), inclusion of downstream users such as consumers. Experts therefore propose a **holistic approach**, taking into account **all dimensions of sustainable development.**

The holistic approach requires that different, partially consistent but also competing objectives are carefully balanced. A significant improvement in the handling of hazardous substances under certain circumstances will also have a direct positive impact on employee health in the chemicals industry and even more so in user sectors as well as on that of the population affected by emissions (SDG 12.4 -> SDG 3.9). The chemical industry has already made tremendous progress in occupational safety and the reduction of greenhouse gas emissions in many countries. With new chemical products, an increase in energy efficiency and thus an indirect contribution to climate action can be achieved. In addition, there are opportunities to switch to renewable resources and to use waste as raw materials. These developments are all the more important since the increase in world population, swiftly advancing urbanization and a continuously growing middle class with considerable purchasing power

[1] http://www.oecd.org/chemicalsafety/risk-management/sustainablechemistry.htm

are leading to a rapid depletion of resources, from drinking water to energy commodities and phosphorus to much needed metals and rare minerals. At the same time, sustainable development presents economic opportunities for industry through innovations and the diffusion of successful business models.

A “green” chemical – that is a chemical which was produced in accordance with the twelve principles of “green chemistry” and “green engineering” – will, however, only then make a contribution to sustainable development when it also contributes, in line with the sustainable chemistry principle, to the avoidance of hazardous waste, lower consumption above all of non-renewable raw materials, climate action and/or other important goals of the 2030 Agenda.

There is sometimes a conflict of interests here between individual SDGs. The concept of Sustainable Chemistry makes this conflict more clearly visible. Regarding maximization of resource efficiency (SDG 12.5), for example: hazardous substances should not be circulated in closed loops. As a result, the recycling of products containing substances classed as hazardous becomes far more difficult or even impossible. Maximization of resource efficiency (EC: circular economy) thus reaches not only physical but also chemical limitations (SDG 12.5). The risks and problems associated with chemicals and waste are rightly addressed in SDG 3.9, 6.3, 11.6, 12.4, 12.5 and 14.1 – these problems need to be solved.

So far, the SAICM approach essentially views the deficits detected in the handling of hazardous substances and waste from the perspective of chemical safety in the narrower sense and attempts to supplement existing regulatory instruments, such as the Basel, Rotterdam, Stockholm and Minamata conventions, on a voluntary basis. Despite all efforts by the stakeholders and sectors involved, it must, however, be stated that what is known as the 2020 Goal, where “by 2020, chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment“, seems unachievable solely with the means available so far. The integration of the concept of Sustainable Chemistry and a corresponding alignment of future “sound management of chemicals and waste” can contribute to reducing deficits detected in the implementation of SAICM. Examining the contribution of sustainable chemistry to economic efficiency, ecological viability and social balance should play a role alongside the necessary rehabilitation of chemically contaminated sites and the determined implementation of global conventions and systems (like e.g. GHS implementation,…). This will facilitate the changeover to less hazardous substitutes and also support the synthesis of intermediates important for industry from raw materials scarcely used to date. Developing and emerging countries can thus exploit new possibilities to use reproducible resources for chemical production.

“Sustainable chemistry is also a process that stimulates innovation across all sectors to design and discover new chemicals, production processes, and product stewardship practices that will provide increased performance and increased value while meeting the goals of protecting and enhancing human health and the environment." (OECD, 2012) Making mandatory the voluntary standards in the chemical industry already introduced in many countries and thus achieving more safety in the handling of chemicals as well as making competition fairer between enterprises are thus helpful for the work being undertaken in the context of SAICM. New and measurable objectives need to be developed in the framework of SAICM to this purpose.

With the expiry of the SAICM mandate in 2020, there is a need for international agreement on a successor platform. At the same time, this also opens up an opportunity to take into consideration not just the strengths and weaknesses of the process to date in the framework of a new mandate. The new mandate should rather take into account future challenges, above all the goals of the 2030 Agenda for Sustainable Development. Sustainable chemistry can make a substantial contribution here. It incorporates ecological viability and social balance but cannot, however, dispense with economic efficiency. The better economic prospects are, the faster it will assert itself. New business models make a contribution here too, such as chemical leasing, use of waste as raw material, more chemicals management services offered by the producers themselves, but also the digitalization and accompanying improvement of communication in the value chain.

The platform for SAICM post 2020 should make use of the possibilities that the concept of Sustainable Chemistry affords (added value) and integrate these into the Overarching Policy Strategy (OPS). This especially concerns the interfaces with the other objectives of the 2030 Agenda and the corresponding SDGs, such as climate action, renewable energies, substitution of hazardous substances by less critical chemicals (viewed over the entire life-cycle), as well as the establishment and implementation of high standards in the approval and handling of chemicals (and hazardous waste). In addition, stakeholders along the value chain must be more actively involved, transparency improved through standardized reporting and suitable indicators developed for measuring progress with regard to the achievement of the SDGs.

2 Status quo

2.1 Global trends and challenges

The satisfaction of basic needs, such as the provision of drinking water, food and living space, is an elementary human right – for everyone. Available resources are becoming ever scarcer and the Earth is increasingly finding itself at the limits of its sustainability. According to the UNRISD Flagship Report 2016[2], the major challenges of our time are “poverty and hunger; climate change; unsustainable growth and economic crises; migration, flight and displacement; health epidemics; inequality; social exclusion; lack of decent work and social protection; as well as political instability, insecurity and violent conflicts.“ These challenges do not stand side by side in isolation. Instead they can far more overlap, increase in a way not always predictable or go hand in hand. Climate change, for example, which is caused in the first instance by unsustainable production and consumption patterns, has a major impact, such as global temperature increase, rise in sea level, ocean acidification, deforestation and desertification, growing shortage of fresh water and cultivable land. It thus deprives people above all in the poorest regions of the world of their livelihood and is subsequently one of the most significant causes of migration.

2.2 The 2030 Agenda for Sustainable Development and the role of the chemical industry

The aim of the United Nations’ strategic plan (Flagship Report 2016[2]) is to enable people everywhere to live a peaceful, decent and dignified life on a healthy planet. To this purpose, the UN member states have adopted the 2030 Agenda and with it 17 SDGs and 169 targets for sustainable development. In their breadth and depth, the SDGs reflect the most pressing problems worldwide and the ones to be solved in the next 15 years.

The 2030 Agenda treats chemicals above all as a problem instigator, see Declaration No. 34: “We will reduce the negative impacts of urban activities and of chemicals which are hazardous for human health and the environment, including through the **environmentally sound management and safe use of chemicals** (see box for description), the reduction and recycling of waste and the more efficient use of water and energy.” Specifically, the following targets 3.9 (Good health), 6.3 (Clean water), 12.4, 12.5 (Responsible consumption and production) and 14.1 (Life below water) are concerned with minimizing the negative impacts of hazardous chemicals and waste as well as their environmentally compatible handling over their entire life-cycle (further details can be found in Section 4). In addition, Goal 9 (Industry, innovation and infrastructure) addresses industrialization in general: 9.2 (Promote inclusive and sustainable industrialization) and 9.4 (By 2030, upgrade infrastructure and retrofit industries to make them sustainable).

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[2] Policy Innovations for Transformative Change: UNRISD Flagship Report 2016. **http://www.unrisd.org/80256B42004CCC77/(httpInfoFiles)/2D9B6E61A43A7E87C125804F003285F5/$file/Flagship2016_FullReport.pdf**

Sound Management of Chemicals
Sound Management of Chemicals throughout their life-cycle means that, "by 2020, chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment. The objective will be achieved, among other ways, through the implementation of activities set out in the Global Plan of Action." (SAICM, OPS, 2006) "**Basic elements for sound management of chemicals are**: (a) adequate legislation, (b) information gathering and dissemination, (c) capacity for risk assessment and interpretation, (d) establishment of risk management policy, (e) capacity for implementation and enforcement, (f) capacity for rehabilitation of contaminated sites and poisoned persons, (g) effective education programmes and (h) capacity to respond to emergencies." (Agenda 21, Chapter 19, Point 56) "The **objective of the sound management of chemicals** is to apply managerial best practices to chemicals throughout their *life cycle* to prevent, and, where this is not possible, to reduce or minimize the potential for exposure of people and the environment to toxic and hazardous chemicals (i.e. through polluting emissions, use, disposal, etc.). This requires strengthened governance, and improved techniques and technologies in the production, use, storage, and disposal or recovery of chemicals." (UNDP: Guide for Integrating the Sound Management of Chemicals into Development Planning, 2012)

The need for a **broad-based and sustainable industrialization** (SDG 9.2 "Promote inclusive and sustainable industrialization") means for industry that it will have to deal with all the facets of its impact on society whereby the **"environmentally sound management of chemicals and all wastes throughout their life-cycle"** is only one dimension (see also Section 2.4). The increasing globalization of production and supply chains poses new challenges for industry. For example, through its choice of energy, raw materials and suppliers of intermediates the chemical industry (like other industrial sectors) also bears the responsibility for the conditions under which these are extracted, generated or produced. These conditions include, above all, observance of human rights and workers' rights, environmental protection and commitment to the fight against corruption, also with regard to suppliers and their subcontractors (see also Section 3.8). These are aspects which are also found in the **holistic approach of sustainable chemistry**, (see also Section 3.1).

The most important of these standards to be observed at the same time form the basis for the ten principles of the UN Global Compact and thus for the leadership of progressive enterprises.[3] These principles in essence also address further SDGs, especially Goal 5 (Gender equality, especially 5.1, 5.2 and 5.5.), 8 (Decent work and economic growth, especially 8.7 and 8.8), as well as 16 (Peace, justice and strong institutions, especially 16.2 and 16.5).

[3] **https://www.unglobalcompact.org/what-is-gc/mission/principles**

2.3 SDGs: Synergies and conflicts of interest

The SDGs are interwoven in many ways. Achieving a goal can lead to synergies for other goals: a significant improvement in the handling of substances hazardous under certain circumstances will also have a direct positive impact on employee health in the chemicals industry and even more so in user sectors (downstream manufacturing) as well as on that of the population affected by emissions (SDG 12.4 -> SDG 3.9). There is sometimes a conflict of interests here between individual SDGs. The concept of Sustainable Chemistry makes this conflict more clearly visible; to give an example: hazardous substances should not be circulated in closed loops. As a result, the recycling of products containing substances classed as hazardous becomes far more difficult or even impossible. Maximization of resource efficiency (EC: circular economy) thus reaches not only physical but also chemical limitations (SDG 12.5). A further conflict of interests can currently be seen between numerous products which are conducive to energy efficiency on the one hand and conservation of resources on the other. For example, products for modern information and communication technologies or electricity generation from wind and solar power require rare materials that can only be obtained through a high input of resources and cannot be recovered again with the methods available today (SDG 7.2, 7.3, 9.c, 17.8 vs. SDG 12.2, 12.5).

The antibiotics required to fight infection can, if the necessary precautions are not taken during their manufacture to prevent their release, end up in the wastewater. This can endanger water quality and promote the development of antibiotic-resistant microorganisms, see also the example of Aurobindo in Section 3.6 (SDG 3.2, 3.3 vs. SDG 3.9, 6.1).

That is why it is necessary when designing chemical products and applications to take into consideration these conflicts of interests too and seek ways to solve them which allow the various goals to be achieved with as few concessions as possible. This is precisely what the sustainable chemistry approach should do.

2.4 Increasing chemicals production and shift of production to developing and emerging countries

The demand for and production of chemicals has grown constantly over the last years. However, this also saw a global shift in chemicals production as well as consumption from Europe to Asia, above all China. An exception is the USA, where the chemical industry was able to expand significantly in comparison to Europe thanks to lower prices for gas and crude oil. The fracking method used there must, however, be classed as unsustainable.

Global chemical turnover: China and USA dominate
In 2013, about 46 % of the € 4,110 billion chemical turnover worldwide could be attributed to just two countries: China (31.4 %) and the U.S. (15.9 %). These were followed at a considerable distance by Japan (5.1 %), Germany (4.8 %), South Korea (3.5 %), France (2.8 %), India (2.4 %), Brazil (2.0 %), Italy (1.9 %), Switzerland (1.6 %), Russia (1.5 %) and the Netherlands (1.4 %). The share of all the

other countries in the world totalled just 25.8 %.[4]

The shift of chemical production to emerging and developing countries is beneficial to the further economic development of these countries. It contributes to reducing inequalities there (SDG 10) and brings people into paid employment which improves their standard of living.[5] In addition, it can help to conserve resources if substances and products are manufactured in proximity to the customer using domestic resources and by means of a type of production which is efficient and low in emissions. Problems can, however, arise in regions where social and ecological standards (such as occupational safety and environmental protection) are low and the legal framework and administrative instruments for proper chemicals management are weak or fail to exist at all. Despite considerable effort at international level, the rules for the approval, classification and labelling of chemicals are inadequate or non-existent in many emerging and developing countries. There are, for example, still tremendous gaps in GHS implementation especially in Central Asia and Africa[6,7]. The same applies for the implementation of SAICM – see the following section and Annex 6.2. That is why it is absolutely essential that a high standard is anchored and implemented **worldwide** for the approval and handling of chemicals (and hazardous waste). **Achieving this will be a very important task for SAICM and sound management of chemicals and waste beyond 2020.**

2.5 SAICM's aspiration – Points of reference for sustainable chemistry

The goal of SAICM is to minimize (significant) negative impacts of chemicals on human health and the environment by 2020 and to make chemicals management safer above all in emerging and developing countries. The **Dubai Declaration** already contains points of reference for **sustainable chemistry** (see box for definition). Point 1, for example, states that environmentally compatible chemicals management is essential to achieving sustainable development. It also points out the advantages offered by chemistry including **green chemistry** (see box for definition), for example for the protection of health and the environment or raising quality of life: *"14. We are determined to realize the benefits of chemistry, including green chemistry, for improved standards of living, public health and protection of the environment, and are resolved to continue working together to promote the safe production and use of chemicals".* Reference is also made to the need to observe the entire life-cycle in the framework of chemicals management (references can be found in the Annex, Section 6.3).

Green Chemistry
"Green Chemistry is **an approach to chemical synthesis** that considers life cycle factors like waste, safety, energy use and toxicity in the earliest stages of molecular design and production, in order to

[4] Data: CHEManager 17/2014 **http://www.chemanager-online.com/news-opinions/grafiken/weltweite-chemie-schwellenlaender-gewinnen-marktanteile**

[5] "Higher incomes can trigger and be associated with purchase of, and improved access to, healthier and more sustainable products, if incentives are created to purchase them." Source: UNEP et al, see footnote 18

[6] **http://www.unece.org/trans/danger/publi/ghs/implementation_e.html**

[7] z.B. **http://ghs.dhigroup.com/GHSImplementatationMap.aspx**

mitigate environmental impacts and enhance the safety and efficiency associated with chemical production, use, and disposal. It takes a life-cycle approach to minimize undesirable impacts that can be associated with chemicals and their production." Source: OECD[8]

Sustainable Chemistry
"Sustainable chemistry is **a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services**. … Within the broad framework of sustainable development, government, academia and industry should strive to maximise resource efficiency through activities such as energy and non-renewable resource conservation, risk minimisation, pollution prevention, minimisation of waste at all stages of a product life-cycle and the development of products that are durable and can be reused and recycled. Sustainable chemistry is also **a process that stimulates innovation** across all sectors to design and discover new chemicals, production processes, and product stewardship practices that will provide increased performance and increased value while meeting the goals of protecting and enhancing human health and the environment." Source: OECD, 2012[8]

Key elements of SAICM are its **Overarching Policy Strategy (OPS)** and the **Global Plan of Action (GPA)** in which the goals to be achieved and the measures for implementing them are formulated and the respective players involved are listed. Neither addresses the points of reference to green or sustainable chemistry to a sufficient degree. For example, the Overarching Policy Strategy (OPS) with its five objectives [9] places the focus above all on chemical safety. The use of **chemicals in products** (= life-cycle approach) should only be incorporated "where appropriate"[10]. So far, only two product categories in the area of chemicals have been included in the Global Plan of Action: nanotechnologies and manufactured nanomaterials and hazardous substances within the life-cycle of electrical and electronic products. Furthermore, of the over 270 activities listed in the GPA not a single one refers explicitly to green chemistry or sustainable chemistry. In addition, there are still gaps in the execution of the GPA in important areas such as implementation of the GHS or avoidance of Highly Hazardous Pesticides (HHPs)[11], see also Table 1 in Annex 6.2.

[8] OECD: The Role of Government Policy in Supporting the Adoption of Green/Sustainable Chemistry Innovations ENV/JM/MONO(2012)3.
http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono(2012)3&doclanguage=en

[9] A. Risk reduction, B. Knowledge and information, C. Governance, D. Capacity-building and technical cooperation, E. Illegal international traffic

[10] 7. Risk reduction (including preventing, reducing, remediating, minimizing and eliminating risks) is a key need in pursuing the sound management of chemicals throughout their entire life cycle **including, where appropriate, products and articles containing chemicals**.

[11] IOMC: IOMC Analysis of the GPA and Proposal for Simple Indicators of Progress. SAICM/ICCM.4/INF.7. August 2014, updated July 2015 **http://www.who.int/iomc/saicm/saicm_iccm4_inf7.pdf?ua=1**

However, good progress could be achieved in many of the GPA's activities, such as "availability of information on chemicals and harmonized risk assessment methodologies, chemical accidents or emergency response[11]". The progress achieved with SAICM and the GPA is also thanks above all to the multi-stakeholder/multi-sector approach of the Overarching Policy Strategy (see Section 6.4). A comparable approach is also pursued with SDG 17 (Revitalize the global partnership for sustainable development[12]).

[12] **http://www.un.org/sustainabledevelopment/globalpartnerships/**

3 Opportunities presented by a stronger focus of international chemicals policy and SAICM on sustainable chemistry as an overarching guiding concept

3.1 Contribution of sustainable chemistry to achieving the SDGs and to the Strategic Approach to International Chemicals Management beyond 2020

How can sustainable chemistry contribute to improving international chemicals management? The key lies in the holistic approach of the concept of Sustainable Chemistry, which is in line with the 2030 Agenda: "The SDGs represent the major overarching principle in which sustainable chemistry is embedded. Chemical products or improvements in chemical processes that are in accordance with the ideas behind the SDGs or promote particular goals are considered as part of sustainable chemistry. Chemistry as a materials and solution provider for a large variety of downstream sectors and applications has a large potential impact on the energy and resource efficiency, lifetime, functionality, recyclability, and safety of products in virtually all industrial and consumer areas being more environmentally friendly than alternatives already on the market."[13] This applies for almost all the problems addressed in the SDGs, such as climate action (SDG 7: Heat insulation), transport (SDG 11: Electromobility), energy production and storage (SDG 7: photovoltaics, chemical and electrochemical energy storage). Table 2 in Annex 6.5 shows further ways in which the chemical industry can contribute to the SDGs.

3.2 Benefits of sustainable chemistry

Sustainable chemistry unites various aspects which can contribute to achieving the 2030 Agenda and co-shape the Strategic Approach to International Chemicals Management beyond 2020. These include, amongst others, the development and use of alternative solutions for problematic applications and the conservation of natural resources, as well as increase of market opportunities and application of corporate social responsibility. Amongst the principles of sustainable chemistry is the idea that a product should be produced in a sustainable manner (process and constituents), contribute in its use to sustainability and be unproblematic in the post-use phase and – if waste is generated – be recycled. For example, in the case of unsafe recycling, the harmful substances contained in waste can considerably endanger workers' health. In emerging and developing countries, a large number of people who "recycle" electronic scrap from industrialized countries using the simplest of means are unwittingly exposed to a wide range of hazardous substances (heavy metals,

[13] Alexis Bazzanella (DECHEMA e.V.), Henning Friege (N³ Nachhaltigkeitsberatung Dr. Friege & Partner), Barbara Zeschmar-Lahl (BZL Kommunikation und Projektsteuerung GmbH): Identification of Priority Topics in the Field of Sustainable Chemistry. Study on behalf of the German Environment Agency, 2017. Environmental Research of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Project number: 3715 65 499 0.

PCBs, flame retardants).[14] Sustainable chemistry confronts these problems and seeks suitable solutions for them. Apart from substituting problematic substances with less problematic ones, this can also include the labelling of the products concerned and a take-back obligation.

Another example is materials for the generation of electricity from renewable energy. Here, recovery and recycling of valuable foils made of high-purity silicon, cadmium telluride etc. from photovoltaic modules are not yet state of the art. The blades of wind power plants are optimized so that they achieve a high energy yield, which mostly goes hand in hand with modifications to their composition (formulae with carbon fibres or carbon fibre/plastic compounds, wood, binders, resins,…). These compounds cannot be broken down into their individual components after use, meaning that valuable resources are lost. The task of sustainable chemistry here is to seek ways to reduce consumption throughout the product's life-cycle.

A further example is the use of pesticides. Whilst this can indeed on the one hand contribute to achieving the SDGs – especially SDG 2 (Zero hunger) – it can, on the other hand and even when used properly, endanger other goals such as health (SDG 3) or clean drinking water (SDG 6), thus leading to a conflict of interests. Sustainable chemistry offers biological control agents (BCA) for this purpose (see also Section 3.5) and – where these are not available (see box) – synthetic pesticides as a **last resort**. Their toxicity should, however, be as low as possible (this also applies for their degradation products) and they should display a high level of selective effectiveness and full biological degradability, not endanger the groundwater and not cause resistance and should be produced in a sustainable manner. Users must learn through information and training how to minimize the dangers for themselves, others and the environment when using these agents. Through their use, not only the health risk for the user decreases but also for the consumers of agricultural products, since these contain less or less problematic residues.

> **Biological control** (including biopesticides) "is not universally appropriate for all pest management situations and there remains an evident and continuing role for chemical pesticides: nevertheless with an increasing proportion of natural products and their analogues."
> Source: ASEAN, 2014[15]

3.3 Continuous further development of a joint understanding of sustainable chemistry

By basing itself on the overarching guiding concept of Sustainable Chemistry, the successor platform for SAICM can only profit. To make progress measurable, more precise impact targets alongside the

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[14] Jerald L. Schnoor (2012): Extended producer responsibility for e-waste. Environmental Science and Technology 46:7927-7927. DOI: **http://dx.doi.org/10.1021/es302070w**

[15] ASEAN Guidelines on the Regulation, Use, and Trade of Biological Control Agents (BCA); ASWGC & BMZ/GIZ, 2014. **www.asean.org/storage/images/Community/AEC/AMAF/OtherDocuments/ASEAN%20Guidelines%20on%20Biological% 20Control%20Agents.pdf**

SDGs and corresponding indicators are needed. The current indicators for assessing progress in SAICM and the GPA are insufficient:[18] "The current international indicators to measure the 2020 goal address some issues of waste management and sustainable consumption and production, but less so chemicals management, in particular chemicals production."

Indicators which are more precise can be derived from a common understanding of sustainable chemistry. Here are examples of two approaches from Germany:

- Quantifiable indicators for sustainable chemistry (Parameters for Sustainable Chemistry – PSC) that serve as a benchmark in and between companies[16]
- The progress indicators of Chemie³ as a benchmark for the sustainable behaviour of a sector[17]

3.4 Common view on chemicals and waste

It is only right that there are institutional links between the topics of chemicals and waste within the UNEP: this must lead to the joint development of objectives and strategies in both areas: "A major challenge is to nurture a new way of thinking and attitude change at all levels in order to move away from a silo approach and address chemicals and waste issues in an integrated manner as part of a broader development agenda."[18]

This is a key issue for sustainable chemistry which focuses, amongst others, on the interfaces between substances, materials and products on the one hand and resource and waste management on the other. Since sustainable chemistry as an overarching guiding concept goes beyond the consideration just of synthesis (see box, Section 2.5), when developing effective drugs, for example, their behaviour in the environment is also optimized[19] or the question of the use of such resources in developing and emerging countries plays a role in the search for renewable resources for chemical synthesis[20].

In view of the growing volumes of waste worldwide, the linking of production and product design with the use and waste phases is particularly important. Three key areas should be mentioned here:

- In production, innovative syntheses have already been helpful for about 20 years, e.g. through the transition to homogeneous or heterogeneous catalysis, also with the use of nanoscale

[16] V. Abraham, M. Blepp, A. Joas, D. Bunke: Beiträge zur Nachhaltigkeitsstrategie – Minderung des Ressourcenverbrauchs in der Chemiebranche durch Instrumente der nachhaltigen Chemie, UFOPLAN 3713 93 425

[17] **https://www.chemiehoch3.de/fileadmin/user_upload/Chemie3_Fortschrittsindikatoren_Steckbriefe.pdf**. Accessed 17-01-2017

[18] UNEP, BRS, SAICM, IOMC & Unitar: Integrated National Implementation of SDGs and International Chemicals and Waste Agreements – International Expert and Stakeholder Workshop, Geneva, Switzerland, 11-13 April 2016. Compilation of Participants' Observations, Messages and Insights. **https://www.unitar.org/sites/default/files/uploads/cwm_sdgs_workshop_outcome_report.pdf**

[19] Example: Benign by design drug to obstruct the migration of cancer cells, which is rapidly degraded in waste water after excretion

[20] Example: Changes in the use of tree bark – synthesis of high-quality intermediates instead of using it as mulch (e.g. triterpenes from eucalyptus)

catalysts, in decreasing the number of reaction steps and producing a greater product yield and thus in reducing waste volumes to a fraction in comparison to previous synthesis methods.[21]

- In the material use of key industrial and agricultural waste where, for example, work is being undertaken on a wide scale with lignin (to extract chemical raw materials[22]). This is likely to become very important in future.
- The reduction of material diversity in simple everyday objects, such as plastic packaging, allows genuine recycling in place of the downcycling of soiled and mixed plastic waste common today.

3.5 Opportunities for industry: Innovation's contribution to achieving specific SDGs

A large part of the SDGs addresses above all the developing and emerging countries since these are particularly affected by the challenges identified. The potential contribution of the chemical industry is illustrated by the example of agriculture. Agriculture plays a central role in achieving the SDGs, especially the goals 2 (zero hunger), 12 (sustainable consumption and production patterns) and 15 (sustainable land use). Chemical pesticides are one of the stabilizing factors for the continuation of non-sustainable agricultural production methods. "… achieving targets 2.4 and 12.2 (sustainable production in agriculture) is directly dependent on successes in minimising the intensity of pesticide use. … The implementation of targets 2.4 and 12.2 require a greater application of agroecological principles in agricultural production. For pesticides this means a return to the principles of integrated pest management with the concept of "chemistry as a last resort".[23]

Within Integrated Pest Management (IPM) strategies, biological control agents (BCA) are regarded as most suitable means in the context of appropriate preventative pest management. Biopesticides currently account for 5 % of the total crop protection market (mainly in the USA, the EU and Asia) and are likely to represent over 7 % of that market by 2023.[24] Examples of innovations in the field of agrochemicals that can potentially support the objective of sustainable agriculture are, for example, bacterial nematicides and biofungicides which use naturally occurring soil bacteria, giant knotweed or neem [25].

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[21] Abfallvermeidung bei Produktionen für organische Spezialchemikalien durch den Einsatz weiterentwickelter Katalysatoren (Ed.: German Environment Agency), UBA-Texte 17/03.
[22] **http://newscenter.lbl.gov/2014/08/18/bionic-liquids-from-lignin/**. Accessed 31-01-17
[23] German Environment Agency: Restart of the EU sustainability policy". June 2016, https://www.umweltbundesamt.de/sites/default/files/medien/1968/publikationen/160928_uba_position_eunachhaltig_englisch_barrierefrei.pdf, corrected
[24] Sara Olson: THE BIOPESTICIDE MARKET. AN ANALYSIS OF THE BIOPESTICIDE MARKET NOW AND WHERE IT IS GOING. Outlooks on Pest Management – October 2015, 203-206. DOI: 10.1564/v26_oct_04 **http://cdn2.hubspot.net/hubfs/86611/An_Analysis_of_the_Biopesticide_Market_Now_and_Where_It_Is_Going.pdf**
[25] It must be kept in mind that these innovations need further input of materials and energy. An LCA approach is therefore always necessary to clear the ecological advantageousness.

Numerous developments in the chemical industry support the achievement of SDG 7 (Affordable and clean energy). Such high-tech materials (high-tech does not necessarily mean sustainable) are used, for example in:

- Power generation (e.g. flexible PV modules on the basis of organic semi-conductors)
- Raising efficiency in energy conversion (e.g. NdFeB-based permanent magnets for wind power)
- Energy storage (e.g. further development of high-energy batteries)
- Thermal insulation (e.g. on the basis of nanoscale pores)

As already explained in Section 3.2, it is sometimes necessary to accept a compromise, for example missing the aim of other SDGs such as SDG 12 (Sustainable consumption and production patterns). Careful balance of the alternatives is therefore a must.

3.6 Diffusion of successful business models

Companies which base their corporate strategies on sustainable chemistry also achieve economic success, whereby under certain circumstances other business models have to be introduced. According to the current state of knowledge, these business models include:

- Chemical leasing, where a large number of successful examples have already been introduced in many countries and different sectors
- Active ingredients, where the precise amount is calculated for the specific purpose, e.g. fertilizers whose active ingredients are released into soil and plants exactly as required[26]
- Recovery of resources from waste, e.g. phosphorus from waste water, sewage sludge/sewage sludge ash and animal excrement, for which numerous processes have been developed which are economically interesting in view of rising phosphorous prices[27]

It can be seen from the examination of innovation approaches in the chemical industry that sustainable chemistry business models often demand an intensive dialogue within the value chain and can therefore contribute to commercial success by means of upstream or downstream integration as a strategic measure. This dialogue is made easier through digitalization.

3.7 More transparency through standardized reporting by chemicals producers and industrial users

Sustainable chemistry is unthinkable if the producers and industrial users of chemicals fail to take seriously their corporate social responsibility (CSR). This responsibility extends not only to their own production sites. Moreover, CSR "also applies to the increasingly global supply chains of chemical products and their applications as well as to workers in recycling and disposal facilities and the surrounding living environment."[31] This is attested above all through companies' sustainability reports. Sustainability reporting is directly linked to SDG 12.6: "Encourage companies, especially

[26] Polymer-coated controlled release fertilizers (CRF) contain of water-soluble nutrients (e.g. NPK) that are wrapped in a flexible polymer membrane. The polymer membrane is biodegradable and decomposes within several months to CO_2, NH_4 and water (according to the manufacturer) and should preferably be plant-based. Polymer-coated CRF are offered by several companies, e.g. AGRIUM, ICL, COMPO or HAIFA.
[27] E.g. BioCover AS, Yara:Trap, RecoPhos®, REPHOS®

large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle."

The most popular reporting guidelines, which are broadly in line with the SDGs, are those of the Global Reporting Initiative (GRI). With its G4 Guidelines, GRI has established a framework of indicators, criteria and metrics for reporting, including supply chain and governance aspects. Companies are, however, allowed to use additional metrics to control their sustainability goals and targets. Such additional metrics include, amongst others, solutions with downstream benefits, innovations for alleviating global challenges (such as energy and climate change, water, food, housing and health) and sum of people whose sustainable development challenges have been positively impacted. These are very interesting approaches, whose use for monitoring the success of sustainable chemistry should also be discussed at regional or international level.

3.8 Voluntary contributions by the chemical industry

The chemical industry is one of the key players in the implementation of "sound management of chemicals and hazardous wastes throughout their life-cycle". With its voluntary initiatives, the chemical industry works towards establishing and promoting norms and management systems geared to ensuring consistent industry attention to sound management of chemicals in a given industry. This applies to programs such as the chemical industry's Responsible Care, as well as programs promoting management of particular chemicals in the downstream industries (often these are driven by the chemical manufacturer, working directly with downstream users, where particular hazard profiles require that. Such voluntary industry initiatives are vital, and should be systematically encouraged and reinforced by governments – especially where they promise to elevate industry standards within a developing country.

At the end of 2016, about 550 chemical companies, which are members of the International Council of Chemical Associations (ICCA) and represent over 90 % of the largest chemical companies worldwide, had signed the Responsible Care® Global Charter. Responsible Care is practised in over 60 countries around the world, however with gaps above all in Central Asia and Africa[28].

Another voluntary approach is the initiative "Together for Sustainability (TfS)". "The purpose of TfS is to develop and implement a global audit programme to assess and improve sustainability practices within the supply chains of the chemical industry"[29] on a voluntary basis. To become a member, the company is obliged to adhere to TfS criteria. The main criteria are a) commitment to internationally established sustainability principles (member or public supporter of the UN Global Compact), b) transparency (regularly publication of a sustainability report (GRI) or integrated report), and c) Sustainability ratings: EcoVadis score above 60. As of January 2017, TfS has only 19 members, but

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[28] International Council of Chemical Associations (ICCA): **https://youtu.be/wUrcwFvh0lY** und Responsible Care 2015. **https://www.icca-chem.org/wp-content/uploads/2015/09/2015-Responsible-Care-Status-Report.pdf**
[29] **http://tfs-initiative.com/about-us/**

"collectively, TfS members represent € 180 billion in spend (based on published financial reports) and an estimated € 276 billion in turnover."[30] This corresponds to about 4 % and 7 % respectively of global turnover in chemical products in 2013 (see box in Section 2.4). TfS is not only a useful tool for the chemical industry with which to save costs and preserve its reputation. The global auditing programme is an additional instrument which can be used to implement chemicals management based on international standards amongst suppliers.

3.9 Enhancing the participation of sectors and interest groups

The extraction, production, transport, processing and utilization of substances and materials have a number of impacts throughout their life-cycle. The production and transport of e.g. crude oil are not only relevant for workers' health and safety and environmental aspects but potentially also with regard to the rights of the indigenous population, since drilling for oil can endanger or even destroy their livelihood should an accident occur. A further example: consumers have a right to learn whether products contain substances which can put their health at risk. Labelling requirements for (hazardous) substances in products (e.g. in children's toys) are often inadequate. The holistic concept of Sustainable Chemistry takes up these topics too: "Sustainable chemistry implicates that in addition to the chemical industry, downstream users of substances and materials, manufacturers of products as well as consumers are important players, who have their roles in a systems innovation approach."[31]

Example of stakeholder participation in pharmaceuticals production
According to reports in 2016, coli bacteria were found in the wastewater of a factory belonging to Aurobindo, an Indian company. These bacteria are resistant to six antibiotics. Aurobindo also manufactures for the German market and is even a preferred partner: several German health insurers have discount agreements with Aurobindo as the company is cheaper than its competitors, probably as a result of lower industrial standards [European Public Health Alliance / Changing Markets, 2016[32]]. This example indicating the price policy of health insurers illustrates clearly the responsibility of players other than the pharmaceuticals industry too.

[30] TfS: Annual Activity Report 2015. **http://www.tfs-initiative.com/dl/TfS_Annualactivityreport_2015.pdf**
[31] Blum, C., Bunke, D., Hungsberg, M., Roelofs, E., Joas, A., Joas, R., Blepp, M., Stolzenberg, H-C. (2017): The concept of sustainable chemistry: key drivers for the transition towards sustainable development. Accepted for publication. Sustainable Chemistry and Pharmacy (Elsevier)
[32] European Public Health Alliance / Changing Markets (2016): ARZNEIMITTELRESISTENZ DURCH DIE HINTERTÜR. WIE DIE PHARMAZEUTISCHE INDUSTRIE DIE ENTWICKLUNG VON SUPERBUGS DURCH UMWELTVERSCHMUTZUNG IN IHREN EIGENEN LIEFERKETTEN FÖRDERT. **http://epha.org/wp-content/uploads/2016/09/ARZNEIMITTELRESISTENZ-DURCH-DIE-HINTERTU%CC%88R-FINAL-WEB.pdf** and **http://www.sueddeutsche.de/gesundheit/antibiotikaresistenzen-superkeime-im-pharma-abwasser-1.3210786**

4 Linking of the Strategic Approach and sound management of chemicals and waste with sustainable chemistry

With the expiry of the SAICM mandate in 2020, there is a need for international agreement on a successor platform. At the same time, this also opens up an opportunity to take into consideration not just the strengths and weaknesses of the process to date in the framework of a new mandate. The new mandate should rather take into account future challenges, above all the goals of the 2030 Agenda for Sustainable Development. This is the result arrived at by the CPR Committee of Permanent Representatives to UNEP 2016 [33.]

Sustainable chemistry can make a substantial contribution to achieving the SDGs (see Sections 3.1, 3.2, 3.5). It incorporates ecological viability and social balance but cannot, however, dispense with economic efficiency. The better economic prospects are, the faster it will assert itself. New business models make a contribution here too (see Sections 3.5, 3.6).

Sound management of chemicals and waste does not, however, become obsolete as a result of sustainable chemistry. On the contrary: sustainable chemistry is unthinkable without high standards being anchored and implemented worldwide for the approval and handling of chemicals and hazardous waste. Meeting SMCW requirements is a prerequisite for sustainable chemistry. It is important to expand further already existing voluntary initiatives by the chemical industry in the direction of SMCW (Section 3.8) throughout the world and to accelerate their further development and implementation in practice with the help of a dialogue amongst all stakeholders (see Section 3.9).

The successor platform for SAICM should make use of the possibilities that the concept of Sustainable Chemistry affords (added value) and integrate these into the OPS. This especially concerns the interfaces with the other objectives of the 2030 Agenda and the corresponding SDGs, such as climate action, renewable energies, substitution of hazardous substances by less critical chemicals (viewed over the entire life-cycle), as well as the establishment and implementation of high standards in the approval and handling of chemicals (and hazardous waste). In addition, stakeholders along the value chain must be more actively involved, transparency improved through standardized reporting and suitable indictors developed for measuring progress with regard to the achievement of the SDGs.

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[33] Information note Sound management of chemicals and waste in the SDG context. Open-ended CPR Committee of Permanent Representatives to UNEP, 15-19 February 2016, Nairobi, Kenya
http://synergies.pops.int/Portals/4/download.aspx?d=UNEP-FAO-CHW-RC-POPS-CPR-ChemWastes-SDGs-InfoNote-20160215.English.pdf

5 Annexes

6.1 SDGs with explicit reference to the management of hazardous chemicals and waste

Goal 3. Ensure healthy lives and promote well-being for all at all ages

3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

Goal 6. Ensure availability and sustainable management of water and sanitation for all

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

Goal 12. Ensure sustainable consumption and production patterns

12.4 By 2020, achieve the **environmentally sound management of chemicals and all wastes throughout their life cycle**, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment

12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

Many products and processes in the chemical industry contribute to the achievement of many SDGs, see section 6.5.

6.2 Gaps in the implementation of SAICM's GPA

Table 1: Gaps in the implementation of the GPA in tasks where the IOMC has been significantly involved (selection, non-exhaustive), 2015[11]

Issue	Remaining Gaps
Availability of information on chemicals and harmonized risk assessment methodologies	Work needs to address new chemicals (e.g. nanomaterials), missing information on existing chemicals, new hazard assessment methods (e.g. high through-put screening methods), and to address emerging and unrecognized risks. Availability of information in more languages.
GHS implementation	Not all countries or sectors have yet fully implemented GHS. Further legal implementation in many additional countries is still needed to achieve global implementation of GHS. Increased and continued training is needed, in particular for industry (SMEs) and further awareness-raising for consumers and the general public.
Integration of sound management of chemicals within ministries involved in supporting chemicals production, use and management ("mainstreaming")	Many countries have not yet engaged in or realized mainstreaming of chemicals.
PRTRs	Not all countries have functional PRTR systems in place.
Chemical accidents	No systematic evaluation of the gaps in capacities for prevention, preparedness and response in many countries. More than 50% of countries still do not have access to a poisons centre. Lack of inter-sectoral coordination and communication; lack of capacities for chemical event surveillance and response.
Emergency response	Many countries still lack core capacities to deal with chemical emergencies under IHR; core capacities for responding to chemical incidents need to be improved.
Poisons centres	Many countries still do not have access to a poisons centre – this represents an institutional capacity/resource gap.
Highly toxic/hazardous pesticides (HHPs)	HHPs are still in widespread use, posing significant/severe threats to human health and the environment. Some countries still lack an effective regulatory system for pesticides. In most developing country situations HHPs cannot be used without risk due to local conditions of use and unavailability of appropriate protective and application equipment, or lack of information/access to alternatives.

6.3 Dubai Declaration 2006: Starting points for green and sustainable chemistry

At the beginning at point 1 it is pointed out that an environmentally sound management of chemicals is essential for achieving sustainable development:

> 1. The sound management of chemicals is essential if we are to achieve sustainable development, including the eradication of poverty and disease, the improvement of human health and the environment and the elevation and maintenance of the standard of living in countries at all levels of development;

In addition, the advantages that chemistry, including green chemistry, provides for the protection of health and the environment, for example, or for an increase in the quality of life are referred to:

> 14. We are determined to realize the benefits of chemistry, including green chemistry, for improved standards of living, public health and protection of the environment, and are resolved to continue working together to promote the safe production and use of chemicals;

Attention is also drawn to the requirement of performing life-cycle assessment in the context of chemicals management:

> 11. We are unwavering in our commitment to promoting the sound management of chemicals and hazardous wastes throughout their life-cycle, in accordance with Agenda 21 and the Johannesburg Plan of Implementation, in particular paragraph 23. We are convinced that the Strategic Approach to International Chemicals Management constitutes a significant contribution towards the internationally agreed development goals set out in the Millennium Declaration. It builds upon previous international initiatives on chemical safety and promotes the development of a multi- and cross-sectoral and participatory strategic approach.

6.4 SAICM: Overarching Policy Strategy: Involved stakeholders and sectors

„2. The involvement of all relevant sectors and stakeholders, including at the local, national, regional and global levels, is seen as key to achieving the objectives of the Strategic Approach, as is a transparent and open implementation process and public participation in decision-making, featuring in particular a strengthened role for women."

Main stakeholders are	Individual stakeholders include	Relevant sectors include, but are not limited to
• Governments • Regional economic integration organizations • Intergovernmental organizations • Non-governmental organizations • Individuals involved in the management of chemicals throughout their life-cycles from all relevant sectors	• Consumers • Disposers • Employers • Farmers • Producers • Regulators • Researchers • Suppliers • Transporters • Workers	• Agriculture • Environment • Health • Industry • Relevant economic activity • Development cooperation • Labour • Science

6.5 Contributions by the chemical industry to selected SDGs

In addition to SDG 9 (Build resilient infrastructure, **promote sustainable industrialization** and foster innovation) that it affecting itself, chemical industry also contributes to the achievement of further SDGs.

Table 2: Contributions of the chemical industry to selected SDGs (non-exhaustive)[13]

SDG	Possible Contribution of the chemical industry to reach the SDG
SDG 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	• Biological or biobased agrochemicals (pest control) • New organic fertilizers • New processes for the recovery of nutrients from wastewater/waste • Differentiated use of nutrient input or the development of optimized types of application in agriculture • Food ingredients
SDG 3: Ensure healthy lives and promote well-being for all at all ages	• Novel drugs to treat rare or "orphan" diseases • New drugs for better quality of care, greater access to medication, more consumer choice, and a competitive marketplace that enhances affordability and public health • Rational design of pharmaceutical compounds by Life Cycle Engineering and biodegradability of pharmaceuticals to reduce environmental impact
SDG 6: Ensure availability and sustainable management of water and sanitation for all	• New design of processes requiring less water, new sustainable cooling systems without water, and internal recycling and reuse (Zero Liquid Discharge) • Reduction of the use of fresh water and drinking water re-sources (sustainable use of alternative sources such as desalination and waste water from urban areas)
SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all	• Advanced materials for renewable energy (photovoltaics, wind turbines, batteries, supercapacitors, thermal energy storage etc.) • Chemical energy storage (e.g. Power-to-X)
SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable	• Clean mobility and transport; e.g. materials for batteries, low-carbon fuels etc. • Energy efficient buildings • Coatings for reducing VOCs (inside buildings) and smog/pollutants (building facades)
SDG 12: Ensure sustainable consumption and production patterns	• Feedstock change to lower carbon footprint feedstock (2nd generation biomass, CO_2 as carbon feedstock for chemicals and fuels) • Closing material cycles as good as possible, waste recovery and valorization, design for recycle or higher biodegradability • High functional products for downstream applications

SDG	Possible Contribution of the chemical industry to reach the SDG
SDG 13: Take urgent action to combat climate change and its impacts	• Chemical processes with lower carbon footprint (process intensification, combined heat and power) • Products for energy savings in downstream sectors and applications (construction, buildings, mobility, lighting, materials life- time, energy recovery etc.) • "Decarbonisation" of the chemical industry through alternative feedstock, integration of renewables for energy supply
Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development	• Biodegradable polymers to reduce marine contamination (micro plastics) • Benign antifouling coatings for marine vessels • Foams for oil spillage recovery
SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	• Super absorbent polymers in agriculture for arid and semiarid regions

3 Authors

Prof. Dr. Henning Friege
N³ Nachhaltigkeitsberatung Dr. Friege & Partner
Scholtenbusch 11, D-46562 Voerde
friege@n-hoch-drei.de

N³ Nachhaltigkeitsberatung
Dr. Friege & Partner

Dr. Barbara Zeschmar Lahl
BZL Kommunikation und Projektsteuerung GmbH
Lindenstr. 33, D-28876 Oyten
bzl@bzl-gmbh.de

BZL Kommunikation und Projektsteuerung GmbH