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Stockholm Declaration on Chemistry for the Future

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On May 23rd 2025, the organizing committee of the Nobel Symposium convened a group from science, industry, education, and policy for the official launch of the **Stockholm Declaration on Chemistry for the Future**. The declaration is a call to action for the implementation of chemistry solutions to build a sustainable future. As such, it shares many of the aims of ***RSC Sustainability*** and its themes will be familiar to our authors and readers. Hence, we, the editorial board of *RSC Sustainability* invite you to read and to consider signing the declaration. In the paragraphs below, we point out some of these overlaps to help you to decide.

The declaration's very title harks back to the language of the United Nations World Commission on Environment and Development Report *Our Common Future*,[1] which established the concept of sustainable development. Since then, the concept of sustainability has evolved,[2] and so has that of sustainable chemistry, but in essence it retains the dual aims of implementing the concept of sustainability in the production, use and fate of chemical products and the application of the chemical sciences to achieving a sustainable future. You can find a discussion on this in *An actionable definition and criteria for "sustainable chemistry" based on literature review and a global multisectoral stakeholder working group*.[3]

The declaration is organised around 5 themes of chemical products and processes, the use of hazardous chemicals, chemistry education, data and information, and government policy.

Theme I recognises the need for biodegradable chemicals/materials for products that are inherently dispersed in use, as described in *Studies on poly(butylene succinate) and poly(butylene succinate-co-adipate)-based biodegradable plastics for sustainable flexible packaging and agricultural applications: a comprehensive review*,[4] and design for reuse/recycling of products to enable a circular economy, which was highlighted in *The global burden of plastics in oral health: prospects for circularity, sustainable materials development and practice*.[5] It also calls for a move away from substances containing **elements at risk**[6] and those that present health and environmental hazards to those that are abundant and inherently safer. These hazards are largely caused by utilisation of geological and fossil sources leading to pollution of water, soil and air, and climate change with impacts on health[7] (UNSDGs 3, 6, 7 and 13–15). You can find papers grouped by SDG in our **themed collections**. These remind us that a proposed circular economy[8] and an energy transition have been advocated for many years.

Theme II calls upon companies to be more transparent about their use and generation of harmful chemicals, while recognising that much more needs to be done in the development of robust metrics to evaluate the harms and

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benefits of chemical products (UNSDGs 3, 6, 9 and 12–15).

Theme III focusses on the need for high-quality education for sustainability, in line with SDG 4. This must be globally equitable, truly multidisciplinary and will need to call upon more than just western models of knowledge, as described in *Addressing the global data imbalance of contaminants of emerging concern in the context of the United Nations sustainable development goals*.[9]

Theme IV calls for open, high-quality data accessible to all to enable scrutiny of claims about technologies, both innovative and legacy, which rather than being an SDG itself is necessary for all the SDGs. The RSC subscribes to the principle that, where possible, all data associated with the research in a manuscript should be Findable, Accessible, Interoperable and Reusable (**FAIR**), enabling other researchers to replicate and build on that research. The application of the FAIR principles to enable the implementation of sustainability concepts can be found in *The FAIR principles as a key enabler to operationalize safe and sustainable by design approaches*.[10]

Theme V calls for governments to instigate policies and regulations around chemicals to enable a sustainable future. These must be based on the best available science and other knowledge. In its very first editorial,[11] *RSC Sustainability* proposed itself as a vehicle for research to support the United Nations Science-Policy Panel on Chemicals, Waste and Pollution, which was also finally agreed in **June 2025**, which is a great example of SDG 17 in action.

We believe that you can see from the above that there is a great deal of commonality between the research that appears in *RSC Sustainability* and the Stockholm Declaration on Chemistry for the Future. We could have picked many more examples of this overlap. We encourage you to read and to consider signing the **declaration**.

Whether you choose to sign the declaration or not, such an action can only be a starting point. The Stockholm Declaration is a statement of aspirations, but it presents huge challenges. Estimates vary, but the chemical industry produces more than 50 000 individual compounds and perhaps up to 350 000 mixtures.[12,13] Most of these chemicals are made from fossil resources (mainly oil but also coal and natural gas). Their manufacture releases ~1000 M tonnes of CO_2,[14] around 5% of all greenhouse gas emissions. In many cases the chemicals also produce CO_2 during their lifetime or at the end.

Industry is working hard to reduce the emissions associated with chemical manufacture but decarbonising 50 000 different chemical syntheses is going to take all our chemical know how, intuition and prowess. There are some easy wins. The world's largest chemical reaction is ammonia synthesis from nitrogen and hydrogen; it emits around 1.5% of all CO_2 emissions because the hydrogen required is produced from methane with all the carbon being thrown away as CO_2. Simply changing to "green" hydrogen from electrolysis of water using oversupplied electricity from solar or wind power will eliminate these emissions (for a more detailed discussion of this and the problems of overuse of chemicals with ammonia as an example see the editorial in the second issue of *RSC Sustainability*).[15] For most of the rest of the 50 000 chemicals, the carbon in them from fossil resources must be replaced by renewable carbon such as CO_2 taken from the air, carbon from industrial waste or from plant sources.

If plant sources are to be used, the plants cannot only be grown to make chemicals as there is then often competition between chemicals and food for land. There are a few examples where a by-product from food production can be used to make chemicals but, for the most part, the main plant-based resources will be lignin and cellulose. Lignin, in the woody parts of plants, is available at 80 million tonnes per year of which only about 1–2 M tonnes per year is used to make chemicals.[16] Cellulose, mainly in the green parts of plants, is available at 1.5×10^{12} M tonnes and is the world's most abundant organic polymer.[17] These two annually renewable resources produce more than enough carbon to make all the chemicals we require for our way of living but they contain complex structures and are difficult to breakdown to small building blocks. In addition, they contain large amounts of oxygen whereas fossil fuels are essentially oxygen free.

Most of the chemicals we use contain some oxygen, nitrogen and other elements such as sulfur, phosphorus and halogens. Making them from fossil resources has required the development of highly selective reactions that *introduce* oxygen and other heteroatoms into the molecules. By contrast, using lignin and cellulose to provide direct or functional replacements will require the selective *removal* of oxygen. Entirely new chemistry will be required, all of it embracing the principles of Green Chemistry and the circular economy.

This analysis just concerns the manufacture of the compounds but what happens to them at the end of their life? How can they be repurposed, reengineered or recycled?

There could not be a better or more exciting time to be in chemistry. Are we ready for the challenges? We have to be.

The 1987 United Nations Brundtland Commission defines sustainability as: "meeting the needs of the present without compromising the ability of future generations to meet their own needs". This is often presented in the concept of three pillars environmental, social and economic.[18] All of these will need to be addressed.

Industrialists are already very keen to have sustainable drop-in replacements for their fossil fuel derived compounds and their customers are pressing hard for this, but they usually require these replacements at almost the same cost as the originals. Sometimes this is possible but generally, at least in the early stages of the transition before true economies of scale emerge, the price is likely to be considerably higher. This is more than just a chemistry challenge and will likely require policy interventions by governments.

Theme IV of the declaration calls for full transparency and availability of chemical data. This is a worthy aspiration and open literature publications require such original data. However, the industrial sector works quite differently. Companies are prepared to invest large amounts in research on the basis that, if they make an important discovery, they have the exclusive right to develop and exploit that discovery over a significant number of years (usually 20). Much of the data they accumulate is held in confidence and does not enter the public domain. True transparency would totally disrupt this system and solutions will need to be found that will enable positive innovation to continue.

It is also worth considering that it is rare for all sustainability vectors to be pointing in the same direction at the same time. For example, in a world where there is not full defossilisation of the energy system, if the use of a less toxic reagent in well-controlled chemical processes comes with higher energy needs this will increase the fossil CO_2 emissions over the original process. These types of trade-offs are inherent throughout sustainable chemistry. Robust methods to measure, compare and balance these requirements need to be developed.[19]

None of this is to detract from the Stockholm Declaration on Chemistry for the Future, but it is important to realise that there need to be dramatic advances coming from all of academia, industry and policymakers to achieve chemical sustainability.

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