Chemistry Goes Green

From plastics to pharmaceuticals to dry cleaning, many of life's comforts would be impossible without the chemical industry. Few people choose to live without the benefits of modern chemistry, but often the benefits are associated with other fields, such as medicine, materials, or engineering. Chemistry is more often associated in the public mind with pollution—from dioxins in waste incinerators to accidents in chemical factories, the biggest news about chemistry seems always to be bad. Even at school and the university, it is mainly considered difficult, leading to ever-decreasing numbers of students choosing to major in chemistry in many industrialized countries.

Can chemistry improve its image by improving its environmental credentials? Many chemical industry processes have been or still are highly polluting; for example, by emitting persistent pollutants that could interfere with the hormonal messenger system in aquatic animals and in humans. Organic solvents are particularly problematic, because many are toxic and are not broken down easily in the environment. Waste is another major issue. Vast quantities of plastic packaging end up in landfills, contributing to the waste mountains that plague modern society.

Over recent decades, the chemical industry has been increasingly regulated in order to reduce harmful emissions and effluents and ensure worker safety. The industry has learned that it is often best to cooperate with environmental legislators. Now scientists are calling for an integrated approach that goes beyond regulation of individual chemicals. Green chemistry focuses instead on making whole chemical processes less wasteful and damaging to the environment.

Any such effort must involve academia, as well as industry, if conventional thinking is to be overcome. Three Viewpoints in this issue detail recent progress toward "greening" chemical processes, with a particular emphasis on industrial-scale applications. First successes are likely to come from the fine-chemical sector, especially the pharmaceutical industry, which deals with smaller quantities and is generally more flexible than the commodity-chemicals sector (Poliakoff *et al.*, p. 807). The latter has larger investments in standing plants.

Carbon dioxide is emerging as a powerful alternative to conventional solvents, combining versatility and ease of separation with environmental compatibility (DeSimone, p. 799). Other candidates include ionic solvents, which have recently been shown to be good candidates for use as electrolytes in polymer electrochemical devices.* New solvent-free syntheses have also been reported. The future success of these approaches will hinge not only on their environmental credentials but also on whether they have advantages related to performance, health, and cost.

Conventional plastics build on petrochemical feedstocks and therefore rely on fossil carbon resources. Biodegradable plastics and water-soluble polymers increasingly use annually renewable resources, such as corn. Some of these products can now compete with traditional fibers and packaging materials in terms of both cost and performance. However, without an appropriate infrastructure to collect and dispose of these new, greener plastics, they will end up in dry landfills where they cannot biodegrade (Gross and Kalra, p. 803). In contrast, biodegradable water-soluble polymers are degraded rapidly in existing wastewater treatment facilities.

At present, only a small fraction of industrial production is based on green processes. As the world population continues to increase and living standards in developing countries improve, the need for sustainable use of resources and for environmentally safe processes and products will become more urgent. Only just at its beginning, green chemistry faces an uphill struggle but is claiming its first victories. The Viewpoints in this issue provide a snapshot of some of the key areas in this process.

–JULIA FAHRENKAMP-UPPENBRINK

*W. Lu *et al.*, *Science* 4 July 2002 (10.1126/science.1072651).

CONTENTS

VIEWPOINTS

Science