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Science News
About ORD
Databases
Models & Methods
Opportunities
R & D News Extra
Research Programs
Research Publications
Research Plans & Strategies
Research Topics
Spotlight on ORD Researchers
Archives

GREEN CHEMISTRY: A 21st Century Approach to Cleaner Chemicals

The Office of Research and Development (ORD), Clean Processes Branch of the National Risk Management Research Lab's (NRMRL) Sustainable Technology Division is introducing new scientific approaches to a persistent technological challenge of how to synthesize commercially important chemicals without depleting or damaging the environment. Currently, the chemical manufacturing industry generates more than 1.5 billion tons of hazardous waste and 9 billion tons of non-hazardous waste annually. Toxic releases are also a problem. Roughly half of the releases and transfers of chemicals reported through EPA's Toxic Release Inventory are a result of chemical manufacturing. Although many of these releases can be minimized by improving industrial housekeeping and pollution prevention techniques, it is clear that the long-term solution lies in the development of new and cleaner production processes.

The Clean Processes Branch, located in Cincinnati, is focusing on alternative oxidation technologies to address this challenge, since oxidation reactions are used to produce nearly a third of U.S. industrial chemicals such as aldehydes, alcohols, ketones, and carboxylic acids–the building blocks of plastics and synthetic fibers. Conventional oxidation reactions are energy intensive, have low catalytic conversion efficiencies, and generate environmentally hazardous wastes and byproducts. Several commonly used catalysts for oxidation reactions are toxic heavy metals (like chromium or vanadium) or strong acids (like sulfuric or nitric acids). Pollution is inevitable in the loading, recovering, and regeneration of these catalysts. To develop a cleaner alternative process, the ORD researchers have successfully tested the synthesis of chemicals by photocatalytic oxidation of organic molecules using an optically excited, specially prepared catalyst, nano-crystal titanium dioxide. This improved oxidation pathway uses materials that are less toxic, generate less waste, and require less energy than conventional methods. This approach, built upon existing concepts of selective oxidation of organic compounds, is the first of its kind to conduct a rigorous evaluation of the gas and liquid phase photoxidation processes. This use of a specialized photocatalyst for selective oxidation of hydrocarbons in synthesizing chemicals has generated much interest from industry and other research groups. Results of these studies have been published and presented at many conferences, and a patent application has been filed. The success of this technology could potentially lead to the revolutionary use of sunlight and molecular oxygen for the synthesis of chemicals, a concept regarded by research scientists as the "Holy Grail" of chemistry.

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