Turning CO2 and Wastewater into Something Useful, with Support from a Fan

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It’s not often that a breakthrough in sustainable chemistry is influenced by a fan letter. Yet that’s what happened for Yale chemist Hailiang Wang, whose lab creates small-molecule and nanomaterial catalysts that remove unwanted material from the environment — such as carbon dioxide in the atmosphere — and turn it into something useful.

In 2019, the journal Nature published a study from Wang’s lab that featured a new carbon dioxide conversion catalyst. Several weeks later, Wang received an email from Robert Tuttle, a Yale alumnus who winters in Naples, Florida, who had read about Wang’s research.

“Here we are very concerned about water runoff from Lake Okeechobee and its effect on marine life from hazardous algae blooms and red tide,” wrote Tuttle. “As you may know such runoff contains high levels of nitrate and phosphates from agriculture … When heavy rains occur, it has been necessary for the Army Corps of Engineers to release water east or west into rivers flowing toward the Gulf of Mexico or the Atlantic. In past years this has resulted in enormous kills of marine life, toxic effects on human respiration, and loss of tourism revenue.”

At the end of his note, Tuttle offered a suggestion:

“What I am wondering is whether your group or any others research[ing] new materials and chemistries are aware of such problems and might find them worthy areas to study,” he wrote. “With new techniques for catalysts such as you devised for carbon capture emerging, I wondered whether others could be devised for the above [mentioned] environmental concern.”

Now, more than a year later, Wang is able to answer yes.

In a new study published in the journal Nature Sustainability, Wang and colleagues at Yale

and the Southern University of Science and Technology (SUSTech) in China described a new reaction that focuses on wastewater.

The catalytic reaction converts carbon dioxide and nitrate in wastewater into methylamine. Methylamine is a highly-valued chemical used in the synthesis of many pharmaceutical and agrochemical products. It is currently produced by industry using fossil fuels with high-temperature and high-pressure chemical reactions.

The new reaction is composed of at least eight individual steps that are completed in one reaction process — including the reduction of carbon dioxide, the reduction of nitrate, carbon-nitrogen coupling, and further reduction of the coupled intermediate. This unique cascade process is catalyzed by cobalt phthalocyanine derivative molecules supported on the surface of carbon nanotubes, a type of catalyst developed collaboratively by Wang's team at Yale and Yongye Liang's group at Southern University of Science and Technology.

"The reaction we've developed could enable the sustainable synthesis of methylamine from, essentially, environmental wastes, using renewable electricity at room temperature and atmospheric pressure," said Wang, who is an associate professor of chemistry in the Faculty of Arts and Sciences and a faculty member of the Energy Science Institute at Yale's West Campus.

The first author of the study is Yueshen Wu, a former graduate student at Yale who is now at the California Institute of Technology. Yongye Liang of Southern University is co-corresponding author, along with Wang. Zhan Jiang and Zhichao Lin, also of Southern University, are co-authors.

Wang credited his correspondence with Tuttle as part of the inspiration to complete his latest work.

"This research was driven by our persistent interest in applying our expertise in catalysis and electrochemistry to develop solutions to environmental problems," Wang said. "It was also partially motivated by my email conversation with a Yale alumnus."

Read the original article on Yale University.