TAML catalysts safely and effectively remove estrogenic compounds from wastewater

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Catalysts created by Carnegie Mellon University chemist Terrence J. Collins effectively and safely remove a potent and dangerous endocrine disruptor from wastewater.

In a paper published in *Scientific Reports*, Collins' research team and collaborators led by Brunel University London's Susan Jobling and Rak Kanda demonstrate that the catalysts could be a viable option for large-scale water treatment.

As pharmaceutical use has skyrocketed, especially in first-world countries, the amount of drugs released into the water system through wastewater has dramatically increased. Medications designed to disrupt the endocrine system, such as birth control pills and some breast and prostate cancer drugs, can be found in close to 25 percent of the world's streams, rivers and lakes. Studies have shown that these compounds have an adverse effect on the health of wildlife.

In many cases, researchers are finding that male fish in these polluted water sources undergo a process called feminization, which is an indicator that estrogenic contaminants are present in the water. Prolonged exposure to these female hormones can cause males to develop eggs in their testes and leads to the decline of fish populations.

"Unfortunately, some synthetic chemicals, including some everyday chemicals, are powerful endocrine disruptors and they often turn up as contaminants in water. These chemicals, called micropollutants, can be bioactive at low environmentally relevant concentrations and are typically tough to break down," said Collins, the Teresa Heinz Professor of Green Chemistry at Carnegie Mellon. "We need to get these micropollutants out of our water systems. Fish are indicators of what can happen when hormone control systems get hijacked by synthetic chemicals. We humans are also animals with endocrine systems, after all."

When a person takes a drug, that drug travels through their body and what isn't absorbed or broken down is excreted as waste. Conventional wastewater treatment systems are unable to fully remove many of the

harmful chemicals found in today's pharmaceuticals, pesticides and other products. Advanced processes installed at the end of wastewater treatment plants, especially those that use ozone or activated carbon, have been shown to be effective options for reducing micropollutants, but the high financial and energy costs of incorporating these have limited their adoption.

Collins has developed a group of catalysts called TAML activators that offer an alternative treatment option. TAMLs are small molecules that mimic oxidizing enzymes. When combined with hydrogen peroxide, TAML activators very effectively break down harmful chemicals in water. To test the effectiveness and safety of these catalysts, Collins teamed up with the Brunel research team, who are world-class experts in aquatic toxicity and wastewater treatment.

In the current paper, the group demonstrates the efficacy and safety of TAML activators via a series of experiments. First, they showed that TAMLs were able to degrade, in pure water, 17alpha-ethinylestradiol (EE2), a synthetic estrogen found in oral contraceptives and a major cause of fish feminization. They then isolated the early intermediate compounds created as TAMLs degrade EE2, and found that several of these were estrogenic and harmful, too. But, using chemical analysis, the researchers showed that the TAML process was able to effectively degrade these intermediate compounds.

The research group also applied TAML activators to samples of water processed by municipal wastewater plants from the U.K. They found that the TAMLs were able to break down EE2 and other estrogenic compounds and micropollutants in the water.

The researchers were then able to demonstrate in the lab that water treated with TAMLs was not harmful to fish. They exposed male fathead minnows, a common freshwater fish found in many inland waterways, to

water containing EE2. The exposure to EE2 caused a well-known effect—the fish began to feminize. After they used TAMLs to remove EE2 from the water, the amount of vitellogenin, a female egg yolk protein, found in the minnows significantly decreased, signaling a dramatic reduction in feminization. Additionally, the fish did not have any detectable adverse effects from being exposed to the tiny traces of TAMLs in the water.

The researchers plan to test TAMLs against ozone and activated carbon treatment systems. They have shown that TAMLs will be at least as effective, and anticipate that the TAML process will come at a much lower cost. Collins estimates that a kilogram of catalyst could treat tens of thousands of tons of wastewater.

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