Beefing up. Implanted growth promoters help many U.S. cattle gain significantly more weight.

ECOLOGY

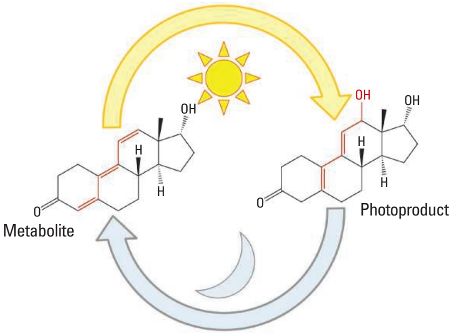
Zombie Endocrine Disruptors May Threaten Aquatic Life

When cattle arrive at feed lots in the United States to be fattened up, many ranchers implant slow-release pellets of steroid hormones to enhance their growth. Only trace amounts of the added hormones remain in the beef after slaughter, but their metabolites can leach from urine and manure. When they reach streams or ponds, some can disrupt the endocrine systems of aquatic life. Industry scientists have noted that many of these metabolites quickly break down in sunlight, which should limit the ecological threat. But they did not reckon with what happens next.

Research online in *Science* shows that the degradation products of a widely used synthetic androgen called trenbolone acetate can revert at night, zombielike, back into the endocrine-disrupting metabolites (http://scim.ag/ShenQu). The same could be true of metabolites of other hormones that make their way into the environment. "This is a very comprehensive and impressive study, and its implications for aquatic ecosystems are sobering," says Karen Kidd of the University of New Brunswick, Saint John, in Canada. "It's a potential game-changer" for ecological risk assessment, adds Deborah Swackhamer of the University of Minnesota, Twin Cities. "My eyebrows went up."

Citing human health concerns, Europe banned trenbolone and other bovine growth-promoters in 1981. Yet the U.S. cattle industry enjoys an estimated $1 billion annual benefit from trenbolone alone: Animals receiving it gain up to 20% more weight per day than they would otherwise and are also more efficient at turning feed into muscle. But environmental concentrations as low as 10 parts per trillion significantly reduce the fecundity of fish and skew the sex ratios of their populations, scientists from the U.S. Environmental Protection Agency have found.

In 2009, environmental engineer David Cwiertny of the University of Iowa in Iowa City and Edward Kolodziej of the University of Nevada, Reno, set out to trace the fate of the hormone and its metabolites. In their early work, Cwiertny and Kolodziej confirmed that the metabolites quickly degrade in sunlight as photons transform a part of their structure called a π-bond. But they also found that the so-called phototransformation products retain some ability to alter the endocrine function of laboratory fish, as their team detailed in the 21 May issue of *Environmental Science & Technology*. "The risk isn't necessarily going to go away," Cwiertny says.



Cyclic. Sunlight turns trenbolone metabolites (*left*) to photoproducts but changes (red) revert at night.

Cwiertny's graduate student Shen Qu then discovered that, at night, a fraction of the two major photoproducts reformed into their parent molecule, the trenbolone metabolites. "That alone is an astonishing result," Swackhamer says. The authors also observed this unprecedented reversible phototransformation of steroids in dienogest, which is used for human birth control, and in the illegal bodybuilding drug dienedione.

What happens, Cwiertny and Kolodziej believe, is that sunlight adds a water molecule across the π-bonds, creating the photoproduct. At night, a chemical reaction spontaneously removes the water. This happens at temperatures and pH typical of surface waters known to be contaminated by trenbolone metabolites. "It makes total sense when you look at it," says Douglas Latch, a photochemist at Seattle University in Washington. "It's unexpected in the sense that no one had designed experiments to find that."

The team found that only about 15% of the metabolites is reformed from the photoproducts during 12 hours of darkness. But the prolonged darkness at the bottom of murky ponds or in the pore-water of streambed sediment may allow much more reversion. After 120 hours without light, the researchers found, up to 70% may be reconverted. For added realism, the team studied trenbolone metabolites added to water taken from the Iowa River, as well as in pond water with manure from implanted cattle. The trenbolone metabolites in the contaminated water underwent the same diurnal cycles of reversion seen in laboratory samples, Cwiertny says.

Regulators need guidance on how to incorporate these findings into risk assessment, says Kathrin Fenner of the Swiss Federal Institute of Aquatic Science and Technology in Dübendorf. "They cannot just be ignored." The researchers themselves say that the implications for human health are minimal, given the small amounts of trenbolone in meat, but that the resurrected endocrine disruptors could be harming aquatic life. Cwiertny adds that the reversion process yields not just the original metabolites but also creates similar chemicals called structural analogs that might have unknown effects. "You're opening the door to additive toxicity," he says.

Ecotoxicologist John Sumpter of Brunel University in Uxbridge, U.K., points out that the new study does not evaluate the biological effects of any of these compounds, so it's impossible to judge whether the photoreversion has any significant ecological impact. A spokesperson for Merck, a large producer of trenbolone, agrees, saying that "the implications of these findings to the environment remain undefined and theoretical." Nonetheless, Sumpter cautions: "Just because a chemical is degraded, don't assume it won't come back to haunt you." **–ERIK STOKSTAD**

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