



By Craig M. Pease

Bad Actors in a Chemical Society

Food is one of the most basic human needs. As described in J. Lieveld and colleagues' recent *Nature* paper, it is not surprising, given a human population of 7 billion, that agriculture is a significant and important global source of air and water pollution.

Two lawsuits filed earlier this year, and grounded in the Clean Air Act and Clean Water Act, seek to address air and water pollution from agriculture. In *Environmental Integrity Project v. EPA*, the plaintiffs demand the agency act on two CAA petitions they filed several years ago, and that EPA has yet to act on. Those petitions ask the agency, inter alia, to regulate ammonia emissions from factory farms. In *Board of Water Works, v. Sac County Board* the plaintiffs ask that the court determine that the defendants' extensive network of drainage ditches, pipes, and other conveyances be treated as point sources under the CWA, and require the defendants to obtain permits to discharge nitrate into public waters.

These two cases entail complex, subtle, and in part untested questions of law. Here it is the law, not the science, that is incipient and uncertain. These two statutes have been responsible for cleaning up many conventional air and water pollution sources. Yet as this has happened, it is a mathematical certainty that an ever

greater share of the remaining pollution will originate from agriculture. Beyond that, there have been huge structural changes in U.S. agriculture since the CWA and CAA were enacted, for example the introduction of factory farms and genetically modified organisms, and increasing farm size and use of nitrogen fertilizer. Yet the black letter of these two statutes has not evolved in response.

Though it is widely understood that burning fossil fuels has dramatically altered the global carbon cycle, it is perhaps less well appreciated that it has just as dramatically altered the global nitrogen cycle. Most of the Earth's atmosphere is nitrogen gas, which is chemically and biologically quite inert. Before that nitrogen is available to most all living animals and plants it must be "fixed," a chemical reaction that turns nitrogen gas into simple compounds.

Nitrogen fixation occurs both naturally and anthropogenically. Mycorrhizae, a symbiosis of a fungus and beans and other plants, fix nitrogen in the soil. And humans fix nitrogen in chemical reactions driven by burning fossil fuels, inadvertently in coal power plants, industrial processes, and motor vehicles, and deliberately in the Haber-Bosch process, central to production of nitrogen fertilizer.

Very roughly, humans now fix about as much nitrogen as is fixed naturally by mycorrhizae. What is perhaps worse, the nitrogen compounds produced when mycorrhizae fix nitrogen mostly stay put, whereas those produced when humans burn fossil fuels roam free across the biosphere, causing us all sorts of trouble.

Just as those who drafted the CAA never intended it as a vehicle to address climate change, so too were the CAA and CWA not enacted as comprehensive means to address agricultural pollution and human alteration of the global nitrogen cycle.

This task is daunting. Though life on Earth is marvelously complex — everything from shrews to slime molds — all living organisms are built from an extremely simple Tinker Toy set, consisting of just four basic parts: the elements carbon, oxygen, hydrogen, and nitrogen. Cutting through the chemical complexity of nitrogen pollution described above, the simple rule is nitrogen by itself as a gas is inert, but chemical compounds that contain nitrogen together with hydrogen or oxygen are much more reactive. Burning fossil fuels, as happens when we produce nitrogen fertilizer, inevitably produces this suite of chemical bad actors.

The global nitrogen cycle is a bit like a human community. This chemical society is composed almost entirely of placid people (nitrogen gas). But alas, it also contains some bad actors who by their very nature are prone to instigate trouble (nitrogen-based compounds such as ammonium and nitrate). We humans have roughly doubled the number of bad actors in the global nitrogen society, and then compounded the

problem by issuing them passports so they can come and go as they please.

This is not good. *Environmental Integrity Project* seeks to rein in ammonium, while

Nitrogen by itself is inert. But add other chemicals and it is an evil character

Board of Water Works seeks to rein in nitrate.

Stamping out these bad nitrogen actors, as they pop up in various contexts and in ever novel ways in agriculture, is going to be a long road. Much better to work for fundamental structural change in our agricultural systems, so those reactive nitrogen compounds mostly stay imprisoned in mycorrhiza, where they belong.

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