Agricultural ammonia emissions disrupt Earth's delicate nitrogen balance

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Credit: NASA

When considering human impacts on earth systems, disturbance to the carbon cycle grabs the headlines. But another critically important earth process, the nitrogen cycle, has also seen major disruption from human activity.

It turns out the nature of that disruption in the U.S. has changed over the last several decades. New Colorado State University research indicates that nitrogen cycle disturbance from emissions of agriculture-related ammonia now exceeds the effects of fossil fuel combustion emissions.

And no matter what the source, excess nitrogen in the atmosphere, as it cycles through terrestrial and aquatic ecosystems in both wet and dry processes, has debilitating environmental impacts. These include increased soil acidification, decreased biodiversity, and changes to the chemistry of lakes and streams.

The research team was led by Jeffrey Collett, professor and head of CSU's Department of Atmospheric Science, and includes collaborators from the Environmental Protection Agency, the National Park Service and the National Atmospheric Deposition Program.

Publishing May 9 in *Proceedings of the National Academy of Sciences*, the researchers describe a slow, measurable shift in sources of nitrogen deposition - the input of reactive nitrogen from the atmosphere to the biosphere - that continue to wreak havoc on ecosystems. The paper's first author is Yi Li, a recent CSU Ph.D. graduate who now works for the state of Arizona.

Starting in the 20th century, human-made nitrogen deposition has come from two main sources: nitrogen oxides from fossil fuel emissions, which become nitrates in the atmosphere; and ammonia, which derives mostly from livestock waste and from nitrogen fertilizers, and which cycles through ecosystems as ammonium.

Over recent decades, most attention has been focused on the fossil fuel side of the equation. In that time, major strides have been made to stem those emissions, through technological improvements and government regulations. Tailpipe emissions are cleaner than ever today, and power plants are tightly regulated for nitrogen oxide pollutants.

In contrast, ammonia from agricultural processes has received little attention, and ammonia is not a regulated pollutant. The CSU researchers have found that ammonium has now surpassed nitrates as the dominant

source of nitrogen deposition and subsequent disruption to the nitrogen cycle.

"We are used to thinking of nitrates as driving a lot of the nitrogen deposition, and that was true in the 1980s," Collett said. "But largely because we've reduced nitrates so much while ammonium deposition has increased, the balance is now shifted, and ammonium is now a bigger contributor to nitrogen deposition."

Ammonia emissions, while not toxic to humans at current atmospheric levels, also have secondary effects, the researchers say. Ammonia is a chemical precursor to many particulate matter pollutants that are harmful to humans, including ammonium nitrate and ammonium sulfate.

In the paper, the researchers analyzed the shift in nitrogen deposition sources from nitrates to ammonia in the context of what's called wet deposition, which is nitrogen that enters the nitrogen cycle in the form of rain or snow.

Nitrogen can also undergo dry deposition, which is when a gas molecule or particle in the atmosphere is directly deposited to the earth's surface. Quantification of dry deposition is more challenging, Collett said, and less data is available to analyze those effects. A recent expansion in U.S. ammonia measurements allowed the team to more fully quantify nitrogen dry deposition inputs. These findings further emphasize the importance of ammonia as a main contributor to ecosystem inputs of nitrogen.

The takeaway? "Policymakers need to be thinking about ammonia, not just nitrates," Collett said. "We've worked hard at decreasing nitrates by reducing emissions of nitrogen oxides from fossil fuel combustion, but if we want to continue to make progress on reducing nitrogen deposition, we need to think about ammonia as well."

More information: Increasing importance of deposition of reduced nitrogen in the United States, *PNAS*, www.pnas.org/cgi/doi/10.1073/pnas.1525736113

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